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A

TREATISE ON FRACTURES.

BY

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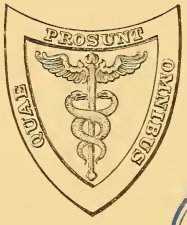

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A

PRACTICAL TREATISE ON FRACTURES.

CHAPTER I.

By *Fracture*, in the surgical sense of the term, is meant the breaking of a bone or cartilage.

The liability to fracture of the different bones of the body varies greatly in consequence of their differences in size, shape, and degree of exposure to external violence or extreme muscular action. Hospital records covering periods varying in length from five to eighty-seven years, have been tabulated by different writers, with the object of determining accurately the relative degree of this liability, and the data thus obtained have served as the basis of most of the opinions current upon this point.

It is evident that such statistics cannot present accurately the desired facts, for the reason that many of the cases of simpler, less important fractures do not need or seek treatment in a hospital. Gurlt, who published in 1862 a most valuable work upon fractures, unfortunately left incomplete, collected six sets of hospital statistics published by other authors, and three sets, one of them being his own, of combined hospital and dispensary practice. The differences are notable, and if Malgaigne's list be taken as the type of one and Gurlt's as the type of the other, it appears that the principal difference is in the relative number of the fractures of the upper and of the lower extremities, Malgaigne giving in a total of 2347 cases 921 fractures of the upper extremity, including the clavicle, and 1024 of the lower extremity, while Gurlt gives in a total of 1631 cases 805 fractures of the upper extremity and only 569 of the lower.

The following table is the one above referred to, of hospital and dispensary patients, and is taken from Gurlt.[1]

[1] Gurlt, Handbuch der Lehre von den Knochenbrüchen, 1862.

Statistics of Fractures Treated in Hospital and Dispensary.

Bones.	Lonsdale, London. Middlesex Hospital, 1831–37.	Blasius, Halle, 1831–56.	Gurlt, Berlin. 1851–56.	Total.
Cranium	48	17	55	120
Nose	13	8	11	32
Sup. max. and zygoma	1	6	10	17
Inf. max.	32	11	13	56
head.	94	42	89	225
Vertebral column	8	4	9	21
Pelvis	7	7	16	30
Ribs	357	37	104	498
Sternum	2	2	4	8
Scapula	18	4	25	47
trunk.	392	54	158	604
Clavicle	273	113	123	509
Neck of humerus	13	15	57	85
Shaft	89	55	75	219
Condyles	16	6	84	106
Forearm	93	69	137	299
Radius	197	57	128	382
Ulna	66	26	28	120
Olecranon	30	13	16	59
Metacarpal	50	20	34	104
Phalanges	66	45	123	234
upper extremity.	893	419	805	2117
Neck of femur	181 fem.	21	76	510
Shaft and condyles		76	156	
Patella	38	20	22	80
Leg	197	94	173	464
Tibia	41	30	36	107
Fibula	51	15	42	108
Malleoli	..	..	32	32
Tarsus and metatarsus	3	7	23	33
Phalanges	11	..	9	20
lower extremity.	522	263	569	1354
Unknown	.....	.....	10	10
	1901	778	1631	4310

Shortly afterwards Gurlt[1] published the following table made up from twenty annual reports of the London Hospital. Its numbers are much larger than those of any other collection, but the details are somewhat scanty. So far as it goes it confirms Gurlt as against Malgaigne.

[1] Langenbeck's Archiv, 1862, vol. iii. p. 394.

FRACTURES IN LONDON HOSPITAL 1842–1862.

	In Hospital.		"Out-patients."		Total.	
Head, 630	296 skull		12	204	308	834
	334 bones of face		192		526	
Trunk, 3032	74 spine		1	1,202	75	4,234
	70 pelvis		3		73	
	2790 ribs		1044		3834	
	20 sternum		2		22	
	78 scapula		152		230	
Upper extremity, 1584	285 clavicle		3182	10,285	3417	11,869
	546 humerus		1105		1651	
	384 forearm		4115		4499	
	419 hand		1883		2302	
Lower extremity, 5440	1373 femur		81	239	1454	5,679
	302 patella		5		307	
	3337 leg		82		3419	
	428 foot		71		499	
Totals	10,686			11,930		22,616

He followed this in 1880[1] with the following table made up from the records of the same hospital from 1842 to 1877. The agreement is very close.

FRACTURES TREATED IN THE LONDON HOSPITAL 1842–1877.

	Hospital.	"Out-patients."	Total.	Per cent.	
Skull	730	27	757	1.457	Head 2002
Face	732	513	1.245	2.397	3.854 per ct.
Spine	169	3	172	0.331	Trunk 9067 17.457 per ct.
Pelvis	139	3	142	0.273	
Coccyx	5	10	15	0.028	
Ribs	4,784	3,477	8,261	15.905	
Sternum	45	7	52	0.1	
Scapula	135	290	425	0.818	
Clavicle	382	7,458	7,840	15.094	Upper extremity 27,119 52.214 per ct.
Arm	1,064	3,020	4,084	7.863	
Forearm	709	8,731	9,440	18.175	
Hand	856	4,899	5,755	11.080	
Thigh	3,072	171	3,243	6.243	Lower extremity 13,750 26.473 per ct.
Patella	649	15	664	1.278	
Leg	8,067	256	8,323	16.024	
Foot	965	555	1,520	2.926	
	22,503	29,435	51,938		

The relative frequency of fractures as compared with other surgical injuries is shown by the following facts. During the same period there

[1] Langenbeck's Archiv, 1880, p. 466.

were treated in the same hospital, 5212 dislocations, 98,373 wounds, 23,180 contusions, 39,947 sprains, 20,396 scalds and burns, 3715 dog-bites, and 975 suicidal attempts.

Sex.—All statistics show that fractures are more numerous in men than in women, in the proportion of about three to one, taking all cases, but this proportion varies greatly at different ages. In infancy the difference is slight; in middle life fractures are ten times as frequent in men as in women; between the ages of fifty and seventy years the difference again becomes slight; and after the age of seventy fractures are much more common in women than in men, a reversal of conditions due to a disproportionate increase in the number of fractures of the neck of the femur.

Age.—Tabulation of the fractures contained in Gurlt's table, with reference to the ages of the patients, shows in the first decade 265; in the second, 193; in the third, 274; in the fourth, 224; in the fifth, 154; in the sixth, 155; in the seventh, 72; in the eighth, 38; and in the ninth, 8. These figures are far from expressing the relative frequency of fracture at the different ages, unless they are considered in connection with others showing the relative number of people living at the different periods. Malgaigne did this with accuracy, and, comparing successive periods of five years, found that the period between the ages of fifty-five and sixty furnished the largest number of fractures in proportion to population. It must be borne in mind, however, that his statistics included only hospital cases. Gurlt's corresponding estimate gives the highest proportion of fractures to the period above sixty years of age. He further attributes the frequency of fracture in early childhood to rachitis; an opinion which does not appear to be shared by other writers.

Season.—Ambroise Paré declared that the bones were more fragile when the temperature of the air was below the freezing-point than at other times, and this opinion has been generally held since his time to the extent, at least, of believing that fractures are more common in winter than in summer. Malgaigne overthrew the claim by statistics, except as regards women, who show an increase of nearly one-third in the winter. Gurlt's statistics show that the difference between the two seasons is very slight, and do not confirm Malgaigne's statement concerning the greater frequency in women in winter.

CHAPTER II.

VARIETIES OF FRACTURE.

The varieties of fracture are numerous and are constituted by differences in the extent of the injury to the bone, or to the surrounding soft parts, in the seat and direction of the fracture, in the relation of the fragments to each other, and in the number of bones involved. These varieties may be grouped in five divisions, marked by important clinical differences and containing many subdivisions, as follows:—

1. Incomplete fractures.
   - (*a*) Fissure.
   - (*b*) True, incomplete, "green-stick" fracture; bent bone.
   - (*c*) Depressed.
   - (*d*) Separation of a splinter or of an apophysis.
2. Complete fractures, subdivided according to—
   - (*a*) Direction of the line of fracture into transverse, oblique, longitudinal, toothed or dentate, and V-shaped.
   - (*b*) Seat of the fracture, into fracture of the shaft of the bone, of the neck of the bone, of the epiphysis, intercondyloid, separation of epiphysis; and,
   - (*c*) If communicating with a joint, intra-articular.
3. Multiple fractures, comprising fractures of two or more different bones, two or more fractures of the same bone at different points, comminuted or splintered fractures, impacted fractures, and fractures with crushing.
4. Compound fractures.
5. Gunshot fractures.

The term *simple fracture*, when used in its strictly technical sense, means that the bone is broken at only one point; but it is also in common use, in contradistinction to the term *compound*, to indicate that there is no associated wound of the soft parts which establishes communication between the fracture and the exterior. Some writers make also a class of *complicated fractures* to include cases in which, in addition to the fracture itself, there exists some other important injury, such as the rupture of a nerve or of an artery, or the laceration of a joint; and there are still other terms in use to indicate peculiarities which do not lend themselves easily to the above classification. Such are: *Spontaneous fracture*, a fracture produced by the minimum of violence; *pathological fracture*, a fracture due to previous partial destruction of the bone by a tumor; *recent*, and *old*, or *ununited*, *fractures*. This classification is not claimed to be absolutely correct in the scientific or even in an ana-

tomical sense, but it is a serviceable one, and one recognized by all writers, although some of the subdivisions are differently placed.

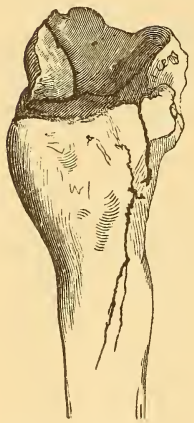
1. Incomplete Fractures.

Under this head will be considered fractures of long bones, in which the continuity of the bone has not been completely lost, and fractures of flat bones in which the line of fracture does not extend from one side to the other.

(*a*) *Fissures.*—This variety of incomplete fracture is characterized by the existence of a split or crack of variable length and depth in the bone, one which does not entirely circumscribe a fragment and separate it from the rest of the bone. It is of common occurrence in the bones of the cranium, not very infrequent in the ribs, and very rare in the long bones, except when associated with other varieties. In the latter case, and when the sides of the fissure are somewhat separated from each other, it is sometimes described as a longitudinal fracture. When several fissures radiate from a central point at which there is usually considerable splintering, depression, or crushing, the injury is called a "starred" or "stellate" fracture.

The existence of this form of fracture in the flat bones, and especially in those of the cranium, has been admitted since the time of Hippocrates. Every pathological museum contains examples of it. In the short or spongy bones it is so rare as to be almost unknown, and it is only of late years that its occurrence in the long bones has been positively demonstrated. This rarity may be due in part to the difficulty of diagnosis when the bone is not exposed to view. A simple fissure of the skull, for example, often passes unrecognized by the finger or the eye until after the peritoneum covering it has been removed.

Fig. 1.



Fissured fracture.

Fissures occur frequently in the long bones in connection with complete fracture, are sometimes very long, and may extend into a neighboring joint. They always involve the entire thickness of the compact substance. They are commonly found in connection with gunshot fractures, and with those produced by great violence, as in falls from a height, and they constitute an important complication in the V-shaped fractures of the tibia.

The examples of simple fissure of long bones unconnected with complete fracture are very rare, but are demonstrative of the fact. Fig. 2, copied by Gurlt from Froriep, represents a linear fracture or fissure extending from the greater tuberosity of the humerus down to the lower fourth of the shaft, produced in a boy by a fall upon the elbow. Four other cases in which the nature of the injury was established by examination of the specimen immediately after the occurrence presented similar, well-defined fissures; one of the humerus, two of the radius, and one of the tibia. These cases are amply suffi-

cient to prove the possibility of this form of fracture without the aid of Malgaigne's clinical proofs, which are not all entirely beyond suspicion as to the correctness of the diagnosis.

Fig. 2.

Fissure of the humerus. (Gurlt.)

The mechanism by which the fissure is produced in long bones, in those cases in which it exists alone, is not definitely known. In two of the cases mentioned above, the immediate, exciting cause was extreme violence exerted upon one end of the fractured bone in a direction parallel to its long axis; this is suggestive of a possible bending of the bone as in "green-stick" fracture, with this difference, that the fracture begins at one end and not in the middle.

This mechanism is shown very plainly in a case reported by Debrou in 1843, and quoted by Gurlt as a case of *infraction* or *bent fracture*. The patient, a man sixty-two years old, fell while walking, and injured his thigh. Erysipelas set in and caused his death. At the autopsy a fissure was found under the unbroken periosteum extending six inches downward from the trochanter minor, and this fissure could be made to widen by pressure upon the ends of the bone.

The diagnosis cannot be made with certainty, except when the bone is exposed to direct examination through a wound of the overlying soft parts; but it can be inferred with much probability in some forms of fracture of the limbs with which it is usually associated, such as perforating gunshot wounds and V-shaped fractures of the tibia, and from the symptoms in fracture of the skull.

Except in the bones of the cranium, or when it extends into a joint, the importance of a fissure is probably slight, and is dominated by that of the associated lesions. It heals, as do other fractures, by bony or fibrous union. In some cases the injury has been promptly followed by suppuration within the bone and a train of consequences ending in death or amputation; in others, suppuration has been discovered two or three months after the injury, under the periosteum, or within the medullary canal, under circumstances which make it probable that it was due rather to direct contusion of the bone than to the fissure itself. The extension of a fissure into a joint is a serious complication.

(*b*) *True incomplete, "green-stick," fracture; bent bone.*

Syn. Fractura incompleta, Infractio. Infraction, Curvature without fracture.

This variety is characterized by a fracture involving only a portion of the thickness of a long bone, and combined with a bending of the bone at the seat of the fracture. It is made by some authors to include also depressions or partial fractures of flat bones, a variety which will be considered in the next section. It includes also the rare cases of simple curvature without recognizable fracture.

It has been objected that a rigid material like bone cannot undergo a sudden, violent, and permanent change of form without fracture of all

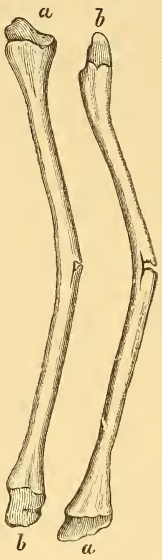
its fibres at the point where the change takes place. The objection is a purely verbal one. It may be, and probably is, true that no permanent change of form can occur without some shifting of the relations between the minute elements, but so long as this shifting cannot be recognized by the means at our disposal, so long as the continuity of the bone is actually preserved, it cannot be said that a fracture exists.

As a matter of fact, ascertained by post-mortem examination and by experiments upon animals and upon cadavers, there exist all degrees of change between simple curvature without recognizable fracture at any point and complete fracture. Anatomically a distinction may be made between simple curvature and partial fracture, but clinically the distinction does not exist. Simple curvature has been produced experimentally in young animals, and occasionally, but very rarely, upon the bodies of young children in the fibula when the tibia has been broken. A clinical and post-mortem demonstration of its occurrence has never been made, if we except a single specimen belonging to Prof. Uhde, of Brunswick, the ulna of an adult much bent by a machinery accident, and showing no trace of fracture. This specimen is mentioned by Gurlt, but without details. After most attempts to produce this variety of fracture expe-

Fig. 3.

Partial or green-stick fracture of the radius.

Fig. 4.



Partial fracture of the fibula. *a*, the head; *b*, the malleolus.

Fig. 5.

Partial fracture of the fibula.

rimentally, careful examination shows a number of minute fractures at the point of greatest curvature. Ordinarily, partial fracture appears as a short transverse fracture, continuous with one or more longitudinal ones of variable length; sometimes there is no transverse line of frac-

ture, but only oblique ones running from the point of greatest curvature upwards or downwards along the shaft of the bone. The appearance can be very closely imitated by over-bending a green or tough stick, a fact that has given this form of fracture the name by which it is very commonly known. The periosteum may or may not be broken at the point or along the line of fracture.

A few instances are recorded of supposed incomplete fracture of the neck of the femur. Here the mechanism and appearance of the fracture are quite different in consequence of the spongy character of this portion of the bone. The line of fracture is transverse and upon the concave side, and is produced by crushing, not by over-bending.

This fracture is seen most frequently in the bones of the forearm, then in the clavicle, and very rarely in the bones of the leg, arm, and thigh. In the forearm the convexity in the great majority of cases is upon the outer side, and the injury is usually the result of a fall upon the hand. It occurs almost exclusively in children, and between the ages of 1 and 14 years. In a case which came under my care in 1882, the patient was a large stout youth of 18. His hand had been caught in machinery, and the forearm twisted about a large shaft; the concavity of the curve was on the anterior and outer side, and I was unable to straighten it entirely.

The chief symptom is deformity, consisting in a more or less marked change in the outline of the limb or bone, a change that can be modified by pressure at its most prominent point, but without crepitation and without abnormal mobility, except sometimes in the plane of the curve itself; in the forearm, for example, the mobility is in the direction of flexion and extension, but is not lateral. There is also localized pain at the seat of the fracture. It is conceivable that this fracture might be produced, and that the elasticity of the bone might be sufficient to restore its shape immediately. The only means of diagnosis in such a case would be the localized pain and the history of the injury.

The prognosis is favorable as regards healing and relief of deformity. Ordinarily, pressure upon the prominent point, with or without moderate extension, will overcome the deformity, and it has been observed in some cases where this could not be completely accomplished at the time that spontaneous restoration of form occurred within a few months. In some cases the deformity cannot be overcome, the bone cannot be straightened, because, apparently, the fragments have become so interlocked as to oppose a mechanical obstacle sufficient to neutralize all the force that it was considered justifiable to apply to the reduction. In Malgaigne's case he evidently, though unintentionally, transformed the partial fracture into a complete one, and I can see no reason why this should not always be done if necessary to obtain reduction when the deformity is great. If the unrelievable deformity is slight, we may safely trust to continuous elastic pressure by means of a splint and a roller or rubber bandage.

It is not necessary that splints or other apparatus should be worn for the same length of time as in cases of complete fracture. The unbroken portion of the bone acts as a splint, and prevents displacement, but the same precautions must be taken against a too early or incautious use of the limb.

(*c*) *Depressions.*

These are incomplete fractures of flat bones, not involving the entire thickness, and accompanied by a bending of the unbroken portion, and a depression of the surface. The most frequent examples are presented by the cranial bones of new-born or young children ; the fracture is on the side towards which the bone is bent, and is accompanied by one or more fissures involving the entire thickness. Malgaigne applies the term also to partial fracture of the ribs, where the fracture is on the outer side, and is produced by crushing. The importance of the injury is generally due to accompanying lesions of the contained viscera, the brain, and the lungs in the cases just mentioned, and under such circumstances the therapeutic indication is to raise the depressed portion of bone. (These must not be confounded with depressed fractures of the skull, in which the entire thickness of the bone is broken and driven in.)

(*d*) *Separation of a splinter or of an apophysis.*

In this variety are included two classes of fractures, which differ widely in their mode of production, but have this in common that the fragment does not comprise the entire breadth or thickness of the bone, and that consequently the continuity of the latter is not destroyed. In the first class a splinter or fragment of bone is broken off by direct violence, often by a cutting instrument or by a bullet; in the second class a bony prominence is torn off by the violent contraction of the muscle or muscles attached to it.

The separation of a splinter or scale of bone by a sword-cut or bullet is not uncommon in the spongy bones or the spongy extremities of long bones, and has also been known to occur in the shaft of the tibia. It is an injury which should be classed rather among wounds of bones than among fractures. The separation of a splinter by direct violence, unaccompanied by a wound of the soft parts, occurs in the bones of the face, at the crest of the ilium, and at exposed points upon the extremities of the long bones. Malgaigne produced it once experimentally upon a rib, breaking off a piece from the lower border, and he quotes from Dandifort the description of two specimens of splinters of the shaft of the femur, one an inch and a half, the other four inches in length. There is no record of the manner in which the injury was produced, and the specimens were obtained after repair had taken place.

Avulsion of an apophysis, or of a scale of bone, by muscular action, is a far more common accident than the one just described. The lesion consists in the fracture of an apophysis at its base, or in the tearing off of a portion of bone to which a muscle or tendon is attached. The fragment may consist of a thin layer of bone corresponding in extent to the muscular attachment and composed almost exclusively of the cortical substance, or it may comprise the entire thickness of an apophysis, as in fracture of the olecranon, of the coronoid process of the ulna, or of the coracoid process of the scapula. In like manner either malleolus may be torn off by forcibly bending the foot to the opposite side, or a condyle or epicondyle at the elbow or knee by forced lateral flexion of the forearm or leg, the force being exerted through the lateral ligaments.

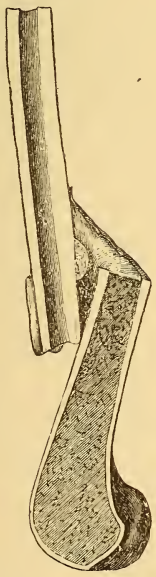
2. Complete Fractures.

The term *complete*, when applied to a fracture of a long bone, indicates that the bone is divided into two or more distinct fragments by a line of fracture crossing its long axis.

(*a*) *The subdivision according to the direction of the line of fracture* has led to much discussion, of which a large part has been wasted upon verbal subtilties. The old division was into transverse, oblique, and longitudinal fractures, names which convey the associated ideas with sufficient distinctness. Malgaigne undertook to limit the term transverse to fractures crossing the shaft of a bone at right angles to its axis—and presenting no marked irregularities of outline or of surface, such a fracture, for example, as would be obtained by breaking a radish, a comparison from which one of the names of this variety, *fracture en rave*, was obtained. He said he had not been able to produce such a fracture experimentally and had not found a specimen of one in any of the pathological museums he had examined. He claimed, therefore, that such a fracture did not exist, except in certain spongy bones or apophyses, such as the acromion, inferior maxilla, and patella, and that those which had been described as such were either oblique or toothed.

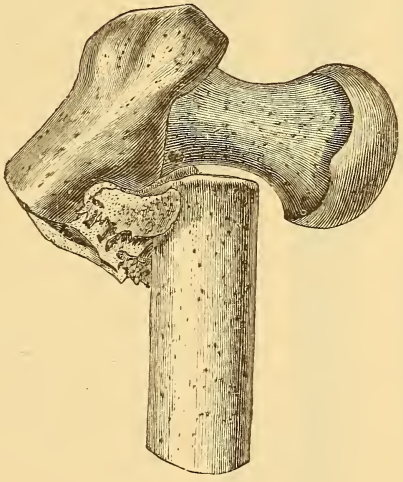
The same observation had been made nearly a century before by Camper, as Malgaigne himself subsequently pointed out, and there can

Fig. 6.



Transverse fracture of the femur. (Gurlt)

Fig. 7.



Transverse fracture of the femur. (Gurlt.)

be no doubt but that the line of the so-called transverse fractures, is, in general, oblique and irregular, as claimed by these authors. But, on the other hand, they erred in being too absolute, for Gurlt has repre-

sented in his subsequent work several specimens, two of which are certainly entitled to be called transverse fractures of the shaft of the femur in the strict sense of the term (figs. 6 and 7), and a third is a transverse fracture through the head of the tibia with splitting of the articular end. Gerdy has also described and figured a similar specimen. The variety, in the strict sense of the term, is, doubtless, very rare, but its existence cannot be denied. It merges into the oblique variety by changes in the general direction of the line of fracture, and into the toothed or dentate variety by increase in the size of the irregularities upon its surface. Clinically, a transverse is distinguished from an oblique fracture by the fact that its general direction is transverse, and prevents overlapping of the fragments, unless there is also associated with it a lateral displacement equal to the diameter of the bone; and from a toothed fracture by the greater abnormal mobility, crepitation, and ease of reduction.

Irregularities of outline, due to the presence of prominences of varying height and breadth of base, are found in all fractures of the shaft of long bones, as might be expected from a consideration of their irregular shape and the variations in the thickness of their cortical layer. It is only when these prominences are sufficiently large to seriously affect the degree of displacement of the fragments and the possibility in the completeness of the reduction that they deserve to be considered as constituting a distinct variety, the *toothed fractures*. The fact that these teeth or prominences may become so wedged together by the violence that causes the injury, that, notwithstanding the completeness of the fracture, its usual signs may be greatly diminished, or even entirely absent, is of especial importance. There may be no abnormal mobility, crepitation, or recognizable displacement, and this may lead to an erroneous diagnosis of simple contusion or incomplete fracture. It is more commonly the case, however, that some of the prominences are broken off, constituting splinters, and that there is an incomplete separation of the fractured surfaces, a separation which it is always difficult and sometimes impossible to overcome completely on account of the interlocking of the smaller fragments and the prominences.

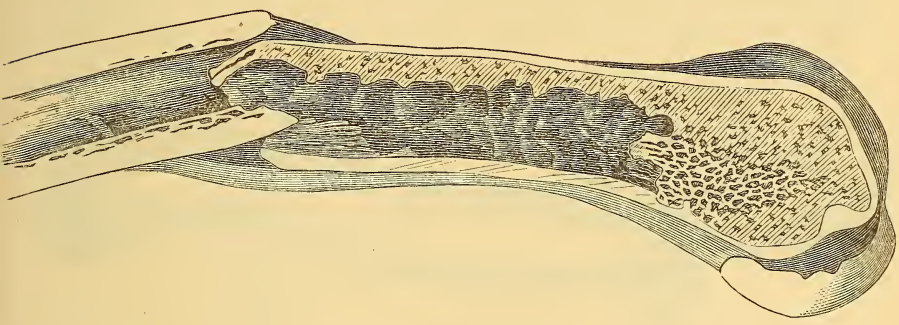
Fig. 8.

Toothed fracture of the femur.

This variety is produced more frequently by direct than by indirect violence or muscular action. In experiments upon cadavers it has been found that fractures produced by a heavy blow upon the shaft of the bone were invariably toothed and usually splintered. This fact is of value in the diagnosis, the difficulties of which have been already mentioned. In the difficult cases anæsthesia may be employed with advantage both for making the diagnosis and correcting the displacement, but it must be remembered that unless displacement exists forcible handling

of the parts with the object only of making an accurate diagnosis is not justifiable. Moderate force exerted by the hands, may be properly

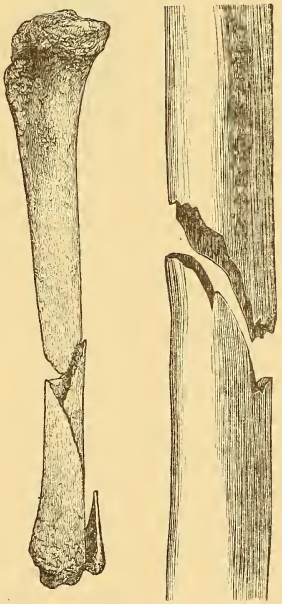
Fig. 9.



Toothed fracture of the tibia.

employed to overcome deformity, even if it results in the fracture of some of the prominences, for the splinters thus produced usually remain adherent to the periosteum and thus preserve their vitality, and do not interfere with recovery.

Fig. 10. Fig. 11.



V-shaped fracture. Oblique fracture of the humerus.

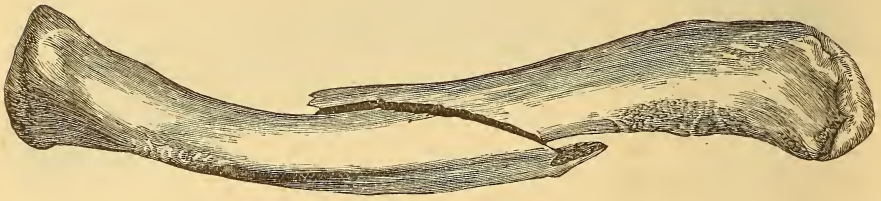
The *V-shaped fracture* of the tibia, first described by Gosselin,[1] is an important variety of toothed fractures. The injury is generally situated in the lower half, or even the lower third, of the leg, and is characterized by a large V-shaped prominence upon the anterior and inner margin of the lower end of the upper fragment, and a similar one upon the posterior margin of the upper end of the lower fragment. From the depression or re-entrant angle in the lower fragment, which corresponds to the first-mentioned prominence, one or two fissures pass spirally downwards and often enter the ankle-joint. It is this fact, together with the difficulty of making the reduction and of maintaining it when made, that gives this variety its importance. It will be described more fully in connection with the other fractures of the tibia.

An *oblique fracture* of a long bone is one in which, as the name so plainly indicates, the direction of the line of fracture is intermediate between the longitudinal and transverse axes of the shaft. Generally speaking, fractures whose direction

[1] Mémoires de la Société de Chirurgie, tom. v., 1855.

does not vary more than 15° or 20° from either axis are not included under this term; they are classified respectively with the transverse and longitudinal fractures. When the deviation from the transverse axis is more than 45°, the fracture is named by the French authors from its resemblance to the mouth-piece of a clarionet, *fracture en-bec-de-flûte* (fig. 12), a fact which deserves mention only on account of the frequency with

Fig. 12.



Oblique fracture of the clavicle.

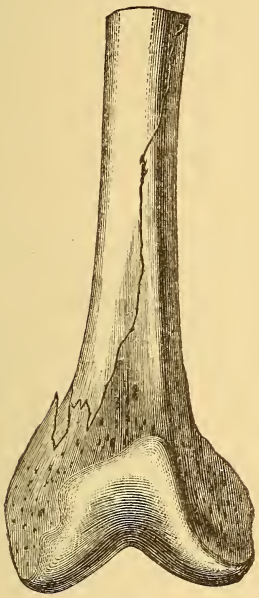
which the term is encountered in surgical literature. The less the obliquity of the fracture, that is, the more nearly it approaches the transverse axis of the bone, the more numerous and prominent are the irregularities upon its surface and the more nearly does it coincide with the toothed fractures above described. The obliquity is greater when the fracture has been produced by indirect violence, and the smoothness of the surface of the more oblique fractures harmonizes, therefore, with the observation previously made, that toothed fractures are usually caused by direct violence. The greatest degrees of obliquity are found in the femur, tibia, and clavicle, more rarely in the arm and forearm, except, perhaps, just above the elbow. The especial clinical importance of the variety is found in the tendency of the fragments to over-ride, to undergo longitudinal and lateral displacements.

Longitudinal fractures are those in which the direction of the line of fracture corresponds more or less accurately to that of the longitudinal axis of the bone. Bouisson, and after him Gurlt, have called attention to the fact that a division of this class into two varieties based upon pathological differences has an important corresponding clinical significance. The simplest and least dangerous kind is one that might be called an extremely oblique fracture, one whose direction is nearly parallel to the long axis although it crosses the bone (fig. 13). The other and more serious kind, is that in which the main line of fracture is more exactly longitudinal, and terminates at one or both ends in a transverse or oblique line. The reason of this difference appears on examination of the different lesions and of the manner in which they are produced. Bouisson[1] produced experimentally the completest, most typical, form of longitudinal fracture, one running the entire length of the bone, and gives a figure of one in the plates attached to his work, but there is no record of such a fracture produced during life and verified by autopsy. The nearest approach to it seems to be one reported by Cloquet in 1831, and quoted by most subsequent writers upon the subject. The patient

[1] L'Union Médicale, 1850, and Tribut á la Chirurgie, vol. i. p. 1.

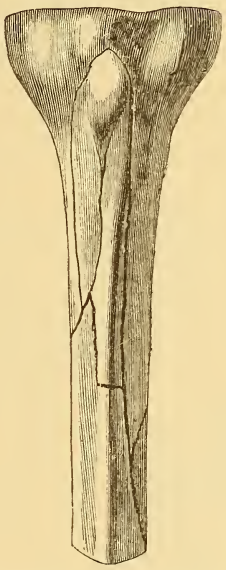
fell from a roof and fractured his femur, the fracture extending from the intercondyloid notch to the trochanter minor; it was exactly longitudinal in the lower four-fifths of its length, and then deflected to terminate on the inner surface of the bone. A case remarkable on many accounts,

Fig. 13.



Oblique fracture of the femur.

Fig. 14.



Longitudinal fracture of the tibia.

and apparently a longitudinal fracture of the most perfect type, was treated in the service of Professor Rose at Zurich, and the account published by his assistant, Krönlein,[1] in a paper on longitudinal fractures. The patient was a man, 27 years old, who received his injury in trying to raise a heavy ladder. The right humerus was fractured longitudinally, presumably through the torsion exerted by the muscles, the fracture running from the shoulder joint to the elbow joint. The man continued to work for four days; the pain and the swelling increased, and he entered the hospital about a week later. Fluctuation became evident in the course of the second month, and evacuating incisions were made at the upper and lower end of the arm, through which the fracture was felt. The edges of the fracture became necrosed, several long sequestra were cast off, and the patient after passing through many complications was discharged cured at the end of two years. Both joints were firmly ankylosed.

Among Bouisson's personal cases the most remarkable on many accounts is one that may serve as an example of the second or more dangerous kind. A man, 21 years of age, was crushed by a falling stone and

[1] Deutsche Zeitschrift fur Chir., 1873, p. 132.

sustained, together with other injuries, a fracture of the femur. Three weeks after the accident the limb became gangrenous and amputation was performed high up. The femur was found to be fractured transversely at two points, one in the lower third, the other just below the trochanter minor, and the intermediate piece, which was eight inches long, was split longitudinally. The patient recovered. Bouisson's experiments were all made upon dried bones, either by subjecting them to extreme violence applied laterally along some prominent ridge or edge by means of a heavy mallet or a vise, or, in imitation of a gunshot injury, by driving a wedge or large nail into them. Laforgue obtained similar results by blows upon the lower end of the femur and upper end of the tibia in the direction of the long axis. The possibility of the fracture is thus established both clinically and experimentally, and can no longer be called in question.

The simpler form is produced usually by indirect violence, and is accompanied by but little splintering; the greater gravity of the other form seems to be due to the direct violence which causes it, to the splintering, and to the crushing or bruising of the marrow, conditions which favor extensive suppuration, and, if the fracture is compound, will probably render amputation of the limb necessary. In only one of the cases collected by Gurlt did the patient save both limb and life, and in that case the fracture was purely longitudinal, without splintering, and without displacement.

The diagnosis even in the simpler form may be difficult unless the bone is so nearly subcutaneous that the outline of the fragments can be felt. In the severer forms it is often impossible to this extent, that while the transverse fracture at either end may be distinguished, the intermediate longitudinal lines may escape detection. When there has been much splintering, a probable diagnosis may be made by attention to the nature of the violence that caused the injury, the extensive swelling of the soft parts, the distribution of the pain over a considerable portion of the bone, the absence of angular displacement or of shortening, and peculiarities in the position where crepitation is found and the manœuvres by which it is obtained, which may indicate the extent of the fracture.

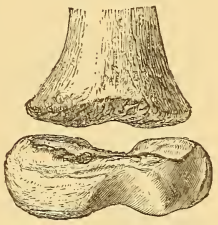
There are no special indications for treatment except that in the severer cases the probable necessity of amputation must be borne in mind, and a decision, based upon the circumstances of each case, must be reached as promptly as possible

(*b*) *Varieties dependent upon the seat of the fracture.* A fracture may occupy any portion of the bone or of its apophyses, and be known by the name of the portion fractured: thus, we speak of fractures of the neck of the femur, of the lower third of the tibia, of the shaft of the humerus, of the internal malleolus, of the outer or inner condyle, and of the acromion. When the fracture extends across the expanded lower end of the humerus or of the femur, and also downwards between the condyles into the joint, it is called *intercondyloid* (fig. 18), and when it follows, in children or adolescents, the line of the conjugal cartilage between the shaft of the bone and the epiphysis, it is called a *separation* or a *disjunction of the epiphysis.* Only the last one requires special

description here, intercondyloid will be spoken of in connection with the intra-articular fractures.

Separation of the epiphysis.—Under this term I shall consider here that class of cases in which, ossification not yet having been completed, a transverse fracture separates the shaft of a long bone from one of its epiphyses. At birth the epiphyses of the main bones of the extremities are wholly, or almost wholly, cartilaginous, and are somewhat longer in proportion to the shaft than they are at the time when ossification becomes complete. The line of demarcation between the epiphysis and the shaft is transverse, except where it is modified by the presence of unossified tuberosities upon the outer surface of the bone. Thus, at the lower end of the humerus the line bends upward to include in the epiphysis the outer and inner epicondyles, and at the upper end of the tibia it sends a tongue-shaped process downward on the anterior surface to include the tuberosity. Ossification begins in these epiphyses by one or more central points, and extends peripherally until it occupies all but a narrow line of cartilage at the junction with the shaft. This line is called the conjugal, or epiphyseal, cartilage, and the subsequent growth of the bone in length takes place upon its central (diaphyseal) surface. The surface of union between the epiphyseal cartilage and the shaft is apparently uniform, but the union is strengthened by minute interlacing prominences in such manner that when an epiphysis is violently separated—portions of the shaft of greater or less size, usually mere scales of bone, are torn off with it. This fact furnishes an additional reason, if one is needed, for including this lesion among fractures. The period at which bony union between the shaft and the epiphysis becomes complete varies with the epiphysis and with the individual. The epiphyses which form the elbow-joint unite before those which form the upper extremity of the humerus and the lower extremity of the radius; while those which form the knee-joint remain ununited longer than those at the opposite ends of the same bones. In females all are united, as a rule, by the 22d year; in males, by the 24th or 25th, yet instances are not lacking in which the conjugal cartilage has persisted until a much later period.

Fig. 15.



Separation of the lower epiphysis of the femur. (Bryant.)

Many experiments have been made to determine the degree and direction of the force necessary to produce this fracture, and to supplement the scanty clinical data concerning its pathology and symptoms. In the very interesting chapter which Gurlt devotes to the subject may be found abstracts of the results obtained by different experimenters. Gurlt himself was unable to separate any of the epiphyses by direct traction, as others had done, but he found no great difficulty in accomplishing it in children less than a year old by forced flexion or extension of the joint, especially of those joints where the normal range of motion is limited, the elbow and knee. He was also able to produce it by fixing the epiphysis, and bending the shaft in the antero-posterior, or in a lateral direction. In the bodies of older children he found it much more diffi-

cult. Salmon[1] produced experimentally complete and incomplete separation, both with and without accompanying fracture of the bone. The periosteum sometimes remained untorn when there was no displacement of the fragments, but usually displacement was accompanied by the stripping off from the shaft of a portion of its periosteum, which remained attached to the epiphysis. The crepitation which can be obtained in complete separation has not the sharpness and distinctness of that which is found after fracture of bone; it can be produced at the elbow after reduction of the displacement by rubbing the fragments quickly backwards and forwards against each other.

Gurlt, in 1862, could collect only seventeen cases of separation of an epiphysis during life in which the diagnosis was verified by dissection; of these, five were of the humerus (4 of its upper and 1 of its lower end), four of the lower end of the radius, five of the lower end of the femur, and three of the tibia. He expresses the opinion that this is a rare accident, and attributes its rarity to the fact that children are seldom exposed to the action of forces sufficiently violent to produce the separation. The histories of these seventeen cases show that the violence was much greater than that which is the usual cause of fracture at the corresponding periods of life. In three of the cases the fracture was produced during the delivery of the child by traction upon the foot, arm, or axilla; in seven by severe falls; in five the limb was caught by machinery or between the spokes of a wagon wheel; and in one separation of the upper epiphysis of the humerus was produced in a child three years old by jerking its arm. With the exception of the three newborn children only one of the patients was less than nine years old; the oldest was eighteen.

On the other hand, the opinion has been held by some that the accident was not by any means so infrequent as the rare mention of it might indicate, and two papers have been published recently in support of this opinion. Vogt[2] reported a case in which the left humerus had become thirteen centimetres shorter than its fellow in consequence of an injury received at the age of ten years, which was probably a separation of the upper epiphysis. He claims that the fracture (separation) without displacement is common in early life, and heals promptly in children of strong constitutions without leaving any evil consequences, while in the weak and strumous it is the frequent cause of suppurative disease of the bone.

Bruns[3] collected eighty-one reported cases in which the diagnosis had been confirmed by direct examination of the seat of injury, either through an associated wound or after amputation or death. In eleven cases the injury was double or multiple; the total being 101, divided as follows:—

[1] Des solutions de continuité traumatiques des os dans le jeune age. Thèse de Paris, 1845. Quoted by Gurlt.

[2] Langenbeck's Archiv, vol. xxii. 1878, p. 343.

[3] Idem., vol. xxvii. 1882, p. 240.

Humerus	upper end	11
	lower end	4
Ulna	upper end	1
	lower end	2
Radius	lower end	25
Ossa pubis		3
Femur	upper end	3
	lower end	28
Tibia	upper end	4
	lower end	11
Fibula	upper end	3
	lower end	4
Metatarsus		2
		101.

In 44 cases the patients were between the ages of ten and nineteen years, and in 8 between one and nine, the maximum of frequency being at about the sixteenth year. Of 61 cases in which the exact description of the fracture was given, 23 were purely epiphyseal separations, 5 fractures through the cartilage, and 33 partly diaphyseal, that is, the line of fracture passed through the "chondroid" tissue at the end of the diaphysis, a tissue which is partly bone and partly cartilage.

He argues that if by a rather hurried search he was able to collect 81 such cases, the number of simple uncomplicated fractures must be very much greater, and that the injury is not an uncommon one.

My personal experience of the subject is limited to 2 cases, both compound. In one a boy thirteen years old caught his foot in machinery and received a compound comminuted fracture of the proximal phalange of the great toe; I could see and feel through the wound the smooth cartilaginous disk limiting the epiphysis. The patient made a good recovery and had a movable joint. In the other, a child about two years old, the upper epiphysis of the right fibula was torn off by the wheel of a street car, and the knee-joint opened. The fracture was exactly at the junction of the epiphysis and the shaft, and the periosteum of the latter was entirely stripped off for some distance, remaining attached to the epiphysis.

The symptoms in the slighter cases described by Vogt, cases which might be classed as partial fractures or even as sprains, are few and indefinite, only the limited line of pain on pressure corresponding to the position of the conjugal cartilage, and the general symptoms of contusion or injury near the joint. When displacement is present the diagnosis of fracture is not usually difficult, its position, the cartilaginous crepitus, and the age of the patient are the points upon which the differential diagnosis must be based. If at the same time the epiphysis is dislocated the injury may be readily mistaken for a dislocation if the examination is not made thoroughly.

The prognosis in the slighter cases is favorable, in the more severe ones it is made grave by the severity of the associated injuries. In addition there is the possibility that in case of recovery the subsequent growth of the limb may be checked by the premature ossification of the

cartilage. This arrest of growth is rare, and even in some of the reported cases the exact nature of the original traumatism is in doubt, for there is reason to believe that premature ossification of the cartilage can be induced by a fracture of the shaft, and the cases are quite numerous in which it has followed inflammation of the bone.

Bruns reported a case in which the shortening of the humerus in an adult following separation of the upper epiphysis at the age of two years was 14 centimetres. Bryant[1] speaks of one in which the shortening of the humerus amounted to five inches, and of another (loc. cit., p. 854) in which the shortening of the tibia amounted to an inch in two years in a child eight years old. Other cases are quoted by Vogt and Bruns.

The principal reason of this non-interference with the growth in most cases appears to be in the frequent situation of the line of fracture in the layer of partly formed bone adjoining the cartilage. The osteogenic layer itself is not directly involved and its function is not interfered with. Another fact, which is a reason why the interference should not be noticed rather than why it should not occur, is that the injury is by far most frequent at an age when the growth of the skeleton is almost completed, and when the result of an arrest of growth, in the upper extremity at least, might easily pass unnoticed. In cases mentioned by Gurlt and Hamilton union failed and a false joint formed, and in one reported by Esmarch[2] a large abscess formed, and led to the removal of the epiphysis and a portion of the shaft (upper end of the humerus); the injury had been mistaken for a dislocation of the shoulder, and two attempts had been made to reduce it.

The treatment requires no especial mention here. It is the same as that of other fractures in the same region, and will be described in connection with the special injuries of the different bones.

(*c*) *Intra-articular Fractures.*—The proximity of a fracture to a joint is always of importance on account of the possibility of the direct implication of the latter in the injury or in the subsequent inflammatory process to which the injury gives rise. The arthritis which may be thus set up adds greatly to the sufferings of the patient, complicates the treatment and endangers the integrity of the functions of the joint. The danger is greatest when the fracture extends directly through the bone into the joint, and to this variety is given the name *intra-articular*. The converse term *extra-articular* is applied to those fractures which are not thus complicated, but whose seat is sufficiently near an articulation to raise the question of the possible communication of the fracture with it.

A fracture of the shaft of a bone may be made intra-articular by a fissure extending into the joint, as in the V-shaped fractures of the tibia and in some gunshot fractures, but much more commonly the main line of fracture involves a portion of the expanded articular extremity of a bone lying partly within the capsule, as in fractures of the condyles of the humerus or femur. Complete fractures of the patella and olecranon are necessarily intra-articular.

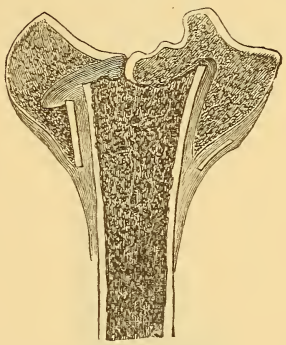
A special signification of the term when applied to fractures of the

[1] Surgery, 3d. Am. ed., p. 834.
[2] Archiv für Klin. Chirurgie, vol. xxi. 1878.

femur must be noted. An intra-articular fracture of the neck of the femur is one in which the line of fracture lies entirely within the capsule; when the fracture is entirely external to the attachment of the capsule it is called extra-articular, and when partly within and partly without it is called a *mixed* fracture. In like manner we speak also of an intra-articular fracture of the neck of the humerus, meaning one that lies entirely within the capsule.

Intra-articular fractures owe their importance to their special anatomical conditions which retard the process of repair, introduce arthritic complications, make proper treatment more difficult, and affect the prognosis. These special conditions are the communication, usually free, between the seat of fracture and the cavity of the joint, the injury to the articular cartilage and the capsule, and in most cases the small size of the fragment which makes it difficult or impossible to apply an efficient retentive apparatus.

Fig. 16.



Intra-articular fracture of the head of the tibia, with impaction and separation of the upper fragments.

The effect of communication between the seat of fracture and the cavity of the joint is that the surface of the former is constantly bathed in the sero-sanguinolent liquid that fills the latter, the lymph which ought to aid in the formation of granulations to unite the broken pieces, is diluted and washed away, so that union, if not prevented entirely, is likely to be fibrous. The fibrous character of the union which is so frequent under these circumstances has been thought to be due to the specific action of the synovial liquid upon the granulations, but the opinion has not been supported by satisfactory proof. The single case reported by Jarjavay and quoted by Follin[1] may have been merely a coincidence. It was that of a man 45 years old, who died of an intercurrent affection on the 42d day after he had fractured the external malleolus. The autopsy showed entire absence of inflammation in the joint or bone; the fragments were in good position, and were united by a fibrous band which presented no trace of cartilaginous or bony structure. Those who claim that the absence of bony union in this case was due to the contact of the synovia, overlook the possibility that it may have been a simple coincidence, and that fibrous union sometimes occurs where this agency is certainly not involved. Sometimes an osteitis is set up in the fragments which, when added to the pre-existing synovitis, is sufficient to cause necrosis of the articular cartilage and probably destroy the future usefulness of the joint.

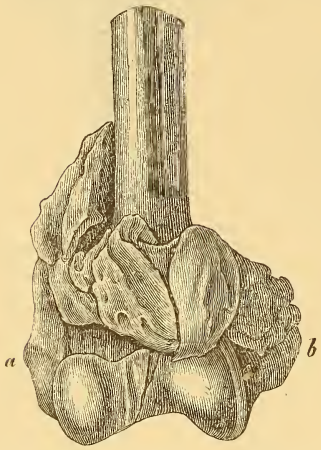
The injury to the other constituent parts of the joint excites therein an inflammatory process which is usually acute, and may end in suppuration; in any case it is followed by a thickening and loss of pliability in the capsule and periarticular tissues, and possibly by the formation of intra-articular bands between the opposing surfaces of bone or capsule,

[1] Pathologie externe, vol. ii. p. 757.

which may permanently restrict the range of motion. An acute arthritis in a large joint is always a serious affection, full of danger to the limb, and even to the life of the patient.

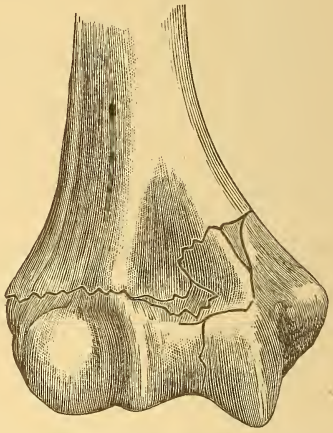
Displacement of the fragments after fracture of the articular end of a long bone, as, for example, of either condyle of the humerus or femur, is favored by the action of the attached muscles, and is difficult to oppose because the fragment is too small to be controlled by the dressing. When the fracture is not only intra-articular but also intercondyloid, that is, when both condyles are separated from the shaft and also from each other, this difficulty is much increased; the two fragments separate laterally, and the other member of the joint is drawn up by the tonicity of the muscles into the interval between them. Consequently, when union has taken place the functions of the joint are found to be diminished, or entirely destroyed, by the change in the relations of the articular

Fig. 17.



Intra-articular fracture of the lower end of the humerus, with exuberant callus, especially in front.

Fig. 18.



Intercondyloid fracture of the humerus.

surfaces to each other, or by overgrowth of the callus in the interval. In young people who have not yet reached their full stature, and whose bones are prone to excessive and irregular formation of callus, this is a frequent cause of crippling, especially at the elbow, where the callus may fill up the olecranon or the coronoid fossa and oppose an insurmountable mechanical obstacle to the movements of flexion and extension. These changes will be studied more fully in connection with the subject of repair of fractures.

The diagnosis in the case of a simple fissure extending from the fracture to the joint can be based upon the nature of the main fracture, upon the fact that certain kinds are usually complicated by fissure, and upon the occurrence of inflammation within the joint; in the other cases, where the fracture occupies the articular end of the bone, it is made by recognition of the size and shape of the fragment and of the deformity.

It often happens that blood escapes so freely from the torn vessels that it fills up the cavity of the capsule, and by preventing palpation of the bony parts makes an exact diagnosis very difficult.

3. Multiple Fractures.

Under this term are included simultaneous fractures of two or more bones in different parts of the body, and two or more fractures of the same bone at different points. The latter variety passes by gradations in the size and number of the fragments into that known as *comminuted fracture*, which will therefore also be considered under this head. The simultaneous fracture of both bones of the forearm, or of the leg, is not called a multiple fracture, and Malgaigne also excludes from this class the fracture of two or more adjoining ribs.

The simultaneous fracture of two or more bones may be produced by a great variety of causes, and its importance, so far at least as the life of the patient is concerned, depends largely upon the immediate cause of the injury. When this cause, as is so frequently the case, is found in the action upon the body of extreme violence, as in a fall from a great height, the explosion of a boiler or of a blast, the caving in of an embankment, or the fall of a heavy block of stone, it often involves such serious injury to other organs, or so much shock to the system, that death terminates the case promptly; or the local injury is so great that the surgeon is called upon, not to treat a fracture, but to perform an amputation. When, on the other hand, the fractures are caused by a moderate violence exerted only upon the limbs which are broken, the prognosis is not much more unfavorable than in similar single fractures. Dupuytren first called attention to the fact that while the danger of wounds and fractures is undoubtedly greater when they are numerous, yet it does not increase in direct proportion to their number; on the contrary, when there are several fractures each one runs a milder course in general than if it were single. Malgaigne and Valette repeat and confirm this statement so far as it relates to simple fractures, and the former suggests as a possible explanation, that when the vital force is thus distributed among several points, it cannot excite as much reaction at each as it could do if confined to a single one.

In Malgaigne's list of 2358 fractures there were 30 patients presenting 67 fractures, counting those of both bones of the leg or forearm or of several ribs as one. They were distributed as follows: One patient having 4, six having 3, and the rest 2 apiece.

Fractures of the	leg	26
" "	thigh	14
" "	arm	7
" "	head	7
" "	clavicle	4
" "	forearm	3
" "	vertebral column	3
Scattering		3

Fracture of a single bone at two separate points is an injury of rare occurrence. The fractures may occupy the shaft alone, or the shaft and one epiphysis (fig. 19), or both epiphyses (fig. 20). So far as known such fractures have been produced only by direct violence, usually a

Fig. 19.

Multiple fractures of both bones of the leg.

Fig. 20.

Multiple fracture of the fibula.

crushing force exerted by a large and heavy body. Sir Astley Cooper[1] reported a case of double fracture of the shaft of the humerus in a man seventy-one years old by a fall against the edge of a curbstone.

Multiple fractures characterized by communicating lines of fracture and the consequent production of several fragments of large size are much more common, and are found in the shafts and epiphyses of long bones and also in short bones. They may be produced by indirect as well as by direct violence, and in their simpler forms are usually the result either of the breaking off of some of the prominences of an oblique or dentate fracture, or of the splintering action exerted upon an epiphysis by the broken end of the shaft. These fragments exert an important influence upon the course and termination of the case; if numerous, and if separated also more or less completely from the periosteum through which alone their nourishment can be assured, they may act as foreign bodies, excite suppuration, and finally be expelled, sometimes only after the lapse of several years. By becoming lodged between the principal

[1] Guy's Hosp. Reports, vol. iv. 1839.

fragments of the shaft of a bone they may prevent complete reduction of the displacement, and render a certain amount of deformity or shortening unavoidable; and when formed by portions of the articular end of a bone they are almost certain to interfere seriously with the future usefulness of the joint by modifying the relations of its opposing surfaces.

Comminuted Fractures.—Strictly speaking, a comminuted fracture is one in which a portion of a bone is broken up into small fragments, and in that sense the term is now generally understood, although Dr. Hamilton[1] uses it as a synonym of *multiple*, without regard to the size of the pieces. That the classification is somewhat vague, and that the boundary-line between this variety and that of multiple fractures is uncertain, is the natural result of the innumerable gradations in size between the largest and the smallest fragments, and of the frequent combination of widely different sizes in a single case, but fortunately this is without importance. This variety also includes *impacted fractures* and *fractures with crushing*, which are of frequent occurrence in the expanded ends of the long bones, especially in the old, and are usually accompanied by absolute loss or destruction of a considerable amount of the spongy tissue.

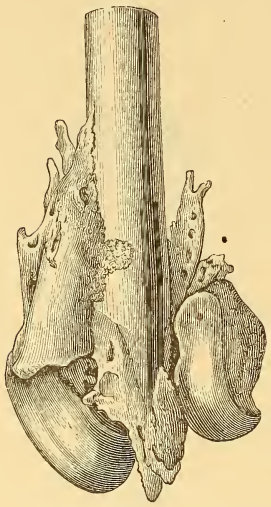
Comminuted fractures present notable differences in the size and number of the fragments and in their relations to each other and the surrounding soft parts. A bone may be broken into many fragments, and yet the relations of the pieces may be well preserved by the support given to them by the periosteum and adjoining tissues. This is especially the case in the short bones and in the spongy portions of the long ones. On the other hand, the fragments may be so numerous and so thoroughly detached, and the surrounding muscles so crushed and torn, that the limb feels like a bag full of bones; or one of the fragments may be driven into another and *impacted* among the pieces into which the latter is split. Under these last conditions the limb is shortened, but abnormal mobility and crepitation may both be prevented by the firmness with which the fragments are wedged together. Permanent deformity is rendered inevitable by the separation of the fragments and the destruction of a certain amount of the spongy tissue.

When the bone has undergone the common senile change characterized by rarefaction of its spongy tissue, interstitial atrophy, this impaction may take place without splitting, but with crushing and practical destruction or condensation of a portion of one or both fragments, and a similar effect is sometimes produced in the short bones without impaction; the bone is simply crushed together or compressed. This is the so-called *fracture with crushing*, and, although most common in advanced life, is frequently seen in the vertebræ without senile change. The meshes of the spongy tissue, which are filled with fat and bounded by thin lamellæ of bone, are broken down and their contents squeezed out, so that an absolute and often considerable loss of substance results, which, if not made good by the formation of new bone, leads inevitably to a permanent deformity, or to a failure of union between the principal fragments.

[1] Fractures and Dislocations, 3d ed. p. 27.

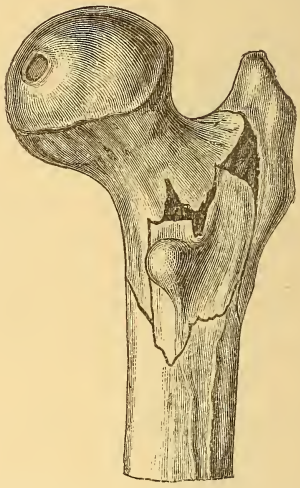
The cause of comminuted fractures of the shaft of long bones is usually direct violence, such as the passage across the limb of a loaded

Fig. 21.



Comminuted fracture of the femur, with splitting of the condyles.

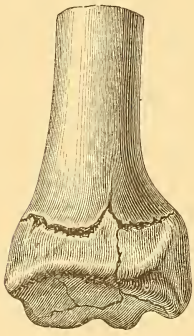
Fig. 22.



Comminuted fracture of the neck of the femur.

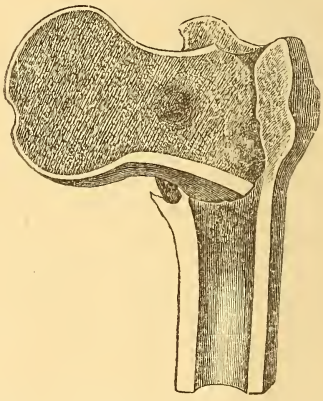
wagon or the fall of a heavy body; in the spongy bones of the foot, or in the vertebræ, it is sometimes produced by a fall upon the feet from a height, and in the expanded ends of the long bones by either direct or

Fig. 23.



Comminuted fracture of the lower end of the radius. Palmar aspect.

Fig. 24.



Impacted fracture of the neck of the femur without splintering. Vertical section.

indirect violence. On the other hand, a comminuted fracture of the neck of the humerus or femur can be produced in persons whose bones have undergone senile change by very slight causes, such as a misstep

or a fall upon the floor while walking. When the injury is caused by direct violence, the soft parts are usually involved to such an extent that the fracture is, or soon becomes, a compound one. In the treatment of compound comminuted fractures, only such fragments should be removed at the first dressing as are entirely loose in the wound or but very slightly attached.

A positive diagnosis of comminution may sometimes be made by direct exploration of the seat of fracture through an accompanying wound, or by palpation of the fragments where the bone is subcutaneous. Under other conditions the surgeon must often be content with a "probable" diagnosis based upon the nature and mode of action of the causative violence, upon the seat of the fracture, and upon the age of the patient.

4. Compound Fractures.

A compound fracture is one in which communication between the seat of fracture and the external air is established through a wound of the soft parts. The existence of this communication has an important influence upon the prognosis, one that depends not upon the simple addition of another traumatism, or upon the greater violence that has caused the fracture, but upon the modification which the contact of the air produces in the process of repair and upon the train of serious complications which may result. The difference between simple and compound fractures is similar to that which exists between subcutaneous and open wounds; in the former, recovery takes place in the great majority of cases speedily and without suppuration; in the latter, suppuration is often inevitable, and the patient is exposed to all the complications to which it may give rise or for which it may furnish the opportunity. It is not the simple addition of an external wound that introduces the element of danger, but it is the communication between the two and the consequent possibility of a change in the character of the reparative process at the seat of fracture, of irritation of the medullary and spongy tissue of the bone, of decomposition of the discharges, and of the absorption of the products of this decomposition which is specially favored by the presence of an open medullary canal, and by the difficulty of properly draining the irregular and deeply situated cavity. A coexistent wound of the soft parts which does not communicate with the fracture, even if in its immediate neighborhood, does not create the same danger, and does not entitle the fracture to be called compound; the fracture remains a simple one and pursues the usual course, the wound usually having no more effect upon it than if it were at a distance, except in so far as it may interfere with the application of a splint. An additional element of danger arises from the usually greater causative violence, and lies in the greater probability of the coexistence of other complications, such as hemorrhage from a wounded vein or artery, rupture of a nerve, or communication of the fracture with a neighboring joint.

It is impossible to make an exact statistical statement of the prognosis in compound fractures, for the reason, among others, that the results obtained in different hospitals vary widely. It is unquestionable that of late years, especially since the more general adoption of antiseptic treat-

ment and the greater care and attention given to obtaining thorough drainage and maintaining cleanliness of the wounds which the discussion of that subject has produced, the results have been much improved. It seems hardly probable that the experience of Volkmann, who, previous to 1873, lost by death three out of every four cases of compound fracture in his hospital service, will ever be repeated; while, on the other hand, the most perfect treatment will not always obviate the necessity for amputation or the risks of hemorrhage, shock, and delirium. As an evidence of what may be obtained by antiseptic treatment, I may quote Mr. MacCormac's report[1] of sixteen successive cases of compound fractures, 2 of the femur, 3 of the upper extremity, and 11 of the tibia, thus treated, which furnished fourteen recoveries, one amputation, and one still under treatment for delayed union. Volkmann,[2] in his address on Surgery before the International Medical Congress in 1881, said he had treated antiseptically 135 successive compound fractures; 133 recovered, 1 died of fat embolism, and 1 of delirium tremens.

Compound fractures are most frequent in the lower extremity, and comprise, according to Gurlt, nearly 16 per cent. of all fractures of the limbs. Excluding fractures of the metacarpal and metatarsal bones and phalanges, they occur most frequently in both bones of the leg, 17.96 per cent.; then in both bones of the forearm, 11.68 per cent.; then in the shaft of the femur, 7.05 per cent.; and then in the humerus, 6.66 per cent. They are most dangerous when the bone is deeply covered by the soft parts, least dangerous when it is subcutaneous.

They are produced by both direct and indirect violence, but more frequently by the former than by the latter, and in that case are much more rarely accompanied by clean-cut wounds than by bruising and crushing of the soft parts. The communicating wound may be made from without inwards, or from within outwards; in the former manner, when the violence is direct, by immediate division of the soft parts down to the bone, or by their subsequent sloughing in consequence of the contusion they have received; from within outwards when the end of one of the fragments is forced through the skin, or when, in the case of an intra-articular fracture with accompanying dislocation, the skin is broken by being stretched across one of the bony edges or prominences of the joint. In both these latter cases the bone projects through the opening in the skin, which is usually small enough to grasp it tightly.

A fracture that is simple at first may be made compound by the sloughing of the skin over the projecting end of a fragment which cannot be properly reduced, or by the subsequent forcing of a fragment through the skin by the careless handling of those who first come to the patient's aid, or by his own act during delirium, or while still in ignorance of the nature of the injury he has just received. Thus, Ambroise Paré, having had his leg broken by the kick of a horse, stepped quickly backward, and bringing his weight upon the broken limb forced the end of one of the fragments through the skin. The English surgeon, Pott, appreciated this danger so fully, that when he suffered the fracture at

[1] British Medical Journal, December 6, 1879, p. 907
[2] Lancet, August 13, 1881, p. 283.

the ankle which is now known by his name, he refused to allow himself to be raised from the ground until a shutter had been brought upon which he could be carried. Gurlt[1] quotes three singular cases in which a piece of the projecting bone was broken off outside the body. In one of them the end of the humerus, broken by a fall from the mast, was forced half an inch into the planking of the deck, and a piece of the bone three inches long broken off; in another a piece of one of the bones of the leg more than an inch long was broken off in the ground by contact with a stone; and in the third a piece of the femur, two and three-quarter inches long and three-quarters of an inch thick, comprising half the thickness of shaft of the bone, was found in the patient's trousers after a fall from a height of twenty feet. All three cases recovered, the last one with an angular displacement for which the patient underwent re-fracture at the hands of Langenbeck.

When the bone projects, or can be seen through the wound, there is of course no difficulty in making the diagnosis. But it is not always so easy. The coexistence of a fracture with the recognized wound of the soft parts may be determined by the usual diagnostic methods, and then the question arises whether or not they communicate with each other. If the wound is large, ragged, and badly bruised, the finger or a probe may be cautiously introduced to feel for bare bone, but as a rule, such explorations are rather to be avoided. If the doubt cannot be otherwise cleared up it is better to consider the fracture a compound one, and treat it accordingly: if it proves not to be one, no harm is done; while if it is compound, the only advantage of such an exploration would be the recognition of fragments that might need to be removed, a rather rare contingency. There are two other symptoms that have a certain diagnostic value, although they are not absolutely pathognomonic; hemorrhage and the admixture with it of drops of fat continuing for several hours after the receipt of the injury. Hemorrhage from the soft tissues alone, unless arterial, does not usually last long, and if arterial can be recognized by its color, while the bleeding from a broken bone is always more profuse and long continued. Drops of fat seen in the blood immediately after the accident may have come from the subcutaneous tissue, but those which appear after the lapse of several hours are much more likely to have come from the marrow of the bone.

The treatment is the same as that of other fractures, with the addition of such measures as are rendered necessary by the wound of the soft parts, and it cannot be too strenuously urged that whenever there is any hope of obtaining primary union of the wound the attempt should be most carefully made, for if it succeeds the fracture becomes a simple one and pursues the usual course of such fractures. When the wound is small and clean-cut, especially if it has been made from within outwards, the surrounding skin should be thoroughly washed with disinfectants after reduction has been made, and the limb has been placed in a retentive apparatus, and then the wound should be covered with a piece of gold-beater's skin, oil-silk, or thin rubber cloth fastened down on three sides by means of collodion. The fourth side, which should be

[1] Loc. cit., vol. i. p. 69.

the dependent one, is left open in order that the blood or discharges may drain away. Then compresses wet with carbolized water should be laid over the wound, and renewed as often as is necessary to prevent decomposition. By this means the wound can be watched as well as if it were exposed, and it is at the same time kept aseptic. This is a modification, introduced by Verneuil,[1] of the old method of treatment by occlusion, and renders it more certain as well as applicable to a larger number of cases. Even if the wound of the skin suppurates, primary union may take place in the deeper portions and serve the same important purpose of rendering the fracture simple instead of compound.

If the soft parts are crushed or a joint largely opened, so that primary union is not to be hoped for, the fracture must be reduced, and the limb perfectly immobilized in an apparatus that will permit the wound to be properly dressed, and by a proper dressing is meant one that secures drainage and cleanliness. The full Lister method is to be highly recommended, but if it is not practicable the surgeon may still hope to obtain an equally good result by the free use of carbolic acid and close attention to the wound. Prof. Markoe[2] has recently introduced a method which has given excellent results both in his hands and in those of others. He passes drainage-tubes through the wound and counter-openings made for the purpose, and injects a 2½-per cent. solution of carbolic acid three or four times each day. He thinks the carbolic acid has a desirable topical effect upon the wounded tissues and favors healing in this manner as well as by preventing decomposition of the discharges. If the wound can be kept aseptic, the dangers of an unsuccessful attempt to save the limb are greatly diminished, and the patient is likely to reach the period when a secondary amputation or excision can be performed with a good prospect of success. By the use of antiseptic measures the surgeon may be often spared the necessity of deciding promptly upon an amputation, a decision which in doubtful cases is always the source of great anxiety, and, when not accepted by the patient, is liable to give rise to unjust and unfavorable comment if he is fortunate enough to escape with his limb and life.

5. Gunshot Fractures.

Gunshot fractures are a variety of compound fractures entitled to separate consideration, not merely by reason of the special nature of the violence that produces them, but also on account of their severity, their numerous complications, and their grave prognosis. In speaking of them as compound fractures the fact that in rare instances a spent ball or fragment of shell may cause a simple fracture is not overlooked, but these cases, although literally gunshot fractures by virtue of their cause, belong more properly to some of the other classes, and have but little in common with the much more grave ones that have a similar origin.

Gunshot fractures may occur in any part of the skeleton, but those which involve the bones of the cranium or the trunk are generally associated with visceral lesions that are either promptly fatal or of such

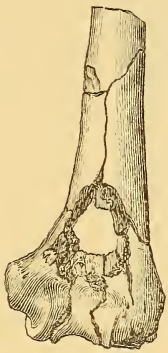
[1] Mémoires de Chirurgie, vol. ii. p. 271.
[2] Am. Journ. Med. Sciences, April, 1880.

importance that the fracture itself becomes a matter of secondary consideration. The fracture, when it involves a long bone, may be either partial or complete; in the former case large or small splinters are

Fig. 25.[1]

Partial fracture.

Fig. 26.[1]



Perforating gunshot fractures of the lower third of the humerus.

Fig. 27.[1]

Gunshot fracture of the humerus.

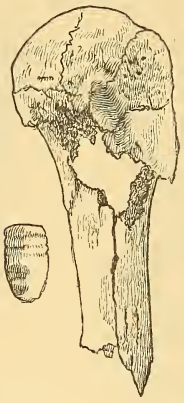
broken off by a ball which strikes some projecting portion of the bone, or glances from its shaft (fig. 25), or, more rarely, perforates it entirely without destroying its continuity. The complete fractures usually show an extreme degree of comminution, with long fissures running up and down the shaft (figs. 26, 27, 28). Usually the ball passes entirely through and beyond the bone, but sometimes fails to do so, and then lies loose in the adjoining tissues or impacted among the fragments (fig. 29). It occasionally happens in the smaller long bones, such as the fibula or the metacarpal bones, that the ball carries away a complete segment of the shaft, and thus creates a gap between the ends of the two main fragments that prevents their subsequent reunion. These are sometimes called "resection fractures." The gravity of shot fractures is due in great part to the degree of comminution, and to the fissures which insure the implication of the marrow in the traumatism to so considerable a distance; the resulting osteo-myelitis increases the chances of pyæmia, and may lead to necrosis of the shaft of the bone and prolonged suppuration, which ends in amputation or in the death of the patient by exhaustion.

The soft parts about the track of the ball are always so bruised and torn that sloughing and suppuration are inevitable; and in civil practice, where the injury is much more commonly caused by the discharge of a

[1] From Med. and Surg. Hist. of the War of the Rebellion.

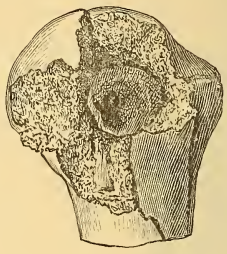
shotgun at short range than by a rifle ball, the destruction of tissue is exceptionally great. The proportion of serious associated injuries to the nerves and bloodvessels is greater than in compound fractures due to other causes, and they are especially liable to declare themselves by

Fig. 28.



Comminuted gunshot fracture of the head of the humerus. (U. S. Med. & Surg. Hist.)

Fig. 29.



Gunshot fracture of the head of the humerus with impacted ball. (U. S. Med. & Surg. Hist.)

secondary hemorrhages, the result of the sloughing of vessels that have been bruised but not immediately divided by the projectile, or that have ulcerated from prolonged contact with the ball, or a portion of clothing, or a fragment of bone. Another important and frequent complication is the implication of a joint by extension of a fissure to it, a complication which may be even more serious in its consequences than if the articular end of the bone were itself the seat of the principal injury, for it may lead to a secondary amputation, whereas under the other circumstances a useful limb may be preserved by resection of the joint, or a primary amputation be performed with a better prospect of success.

The treatment and prognosis of gunshot fracture have been established mainly by the results of military surgery, and are not, perhaps, entirely applicable to cases occurring in civil practice, because the exigencies of the field of battle, the lack of opportunity for the care and precautions that should be immediately taken, the exposure often prolonged, the necessity for repeated transport over bad roads, the crowded hospitals, and the inability of the overworked surgeons and nurses to give each case the attentive personal care which is so desirable, combine to often force an amputation where, under more favorable circumstances, conservative treatment might be successful. The indications also are that the use of carbolized dressings will have the same effect in improving the prognosis with respect to both life and limb in this class of cases that it has had already in others.[1] The choice of treatment lies between amputation, excision of a joint, and pure conservative treatment in which the interference is limited to removal of foreign bodies, provision for thorough

[1] See some remarkable cases of conservative treatment after gunshot wounds of joints in the Russo-Turkish War of 1878–79 in MacCormac's address, loc. cit., and in his Antiseptic Surgery, Smith, Elder & Co., 1880, p. 41.

drainage, and giving exit to pus and splinters when they present themselves. The question will be considered more in detail in the chapter on Treatment, and I shall limit myself here mainly to the restatement of some of the conclusions arrived at by Mr. Longmore,[1] Professor of Military Surgery at Netley, by Professor Langenbeck,[2] and Colonel Otis, the editor of the Medical and Surgical History of the War of the Rebellion. It must be borne in mind, however, that since these opinions were expressed the antiseptic methods of treatment have singularly diminished the necessity for sacrificing limbs to save life.

All authorities recognize the danger of operations undertaken during the intermediary period, that is, during the stage of inflammation and infiltration of the soft parts, which begins from twenty-four to forty-eight hours after the receipt of the injury and lasts until the acute inflammatory processes have terminated in convalescence or in chronic suppuration. An operation therefore must be done at once, or postponed for three or more weeks. Colonel Otis gives the preference unhesitatingly to the primary operation, and so does Mr. Longmore in amputations, while Langenbeck recommends quite as strongly secondary excision of the shoulder and ankle joints, except in rare cases and primary excision of the elbow and possibly of the wrist.

Excision is to be preferred to amputation after shot fracture of the upper articular extremity of the humerus, when the main vessels and nerves are uninjured; and Langenbeck reports two cases to show that extensive laceration of the soft parts is not a contra-indication. For injury of the shaft of the humerus amputation in continuity when possible is always to be preferred to disarticulation, and the United States Reports show very positively that amputation in the lower third is much more fatal than amputation at a higher point, or even than disarticulation at the shoulder.

At the elbow the danger of conservative treatment or delayed operation lies in the facility with which suppuration spreads among the muscles of the forearm, and the disability of the hand which results from this, and the necessary evacuating incisions by reason of adhesions among the tendons. Moreover, conservative treatment, if successful, ends inevitably in ankylosis of the joint. If the vascular and nerve supply of the forearm is uninjured an attempt therefore should be made to save the limb by excision.

Primary amputation of the forearm is condemned by Colonel Otis, "except in rare cases where the tissues are almost disorganized," and he expresses the most unqualified disapproval of the excision of portions of the shafts of these bones. The same writer says it is still uncertain whether or not excision of the wrist for injury is a proper operation, and Longmore expresses a doubt whether a satisfactory result is ever possible, but Langenbeck says,[3] that when the epiphyses of the radius and ulna and the carpal bones are shattered, especially if the ball has lodged in the wound, primary excision is certainly indicated; while after simple

[1] Holmes's System of Surgery, vol. ii. 1870.
[2] Archiv für Klin. Chirurg., vol. xvi. 1874.
[3] Loc. cit., p. 462.

perforation of the wrist, he would treat conservatively, and resect without delay whenever commencing infiltration of the forearm could not be checked by incisions.

After shot fractures of the upper articular end of the femur, primary amputation has proved so fatal that it is now practically abandoned, and the choice lies between conservative treatment and excision. Both measures have yielded a small proportion of successes. In those of the upper third, where the joint was not involved, the results of conservative treatment have been a little less bad than those of amputation. Shot fracture of the middle and lower thirds of the femur calls, as a rule, for primary amputation, for conservative treatment has furnished a considerably larger percentage of mortality.

In fractures of the leg involving the knee-joint experience shows amputation to be by far the safest treatment. Excision has given very bad results, which Langenbeck, however, thinks might be improved by the use of the immovable plaster splint. Conservative antiseptic treatment has recently furnished results which, if confirmed by further experience, will reverse this conclusion. Dr. Reyher, a surgeon in the Russian army operating in the Caucasus, reports eighteen cases of gunshot wound of the knee-joint treated conservatively and antiseptically, with only three deaths.[1] The limb was saved in fifteen cases, and with a movable joint. Fractures of the leg not involving either joint have done well under conservative treatment. Fractures of the ankle have been thought to require immediate amputation, and excision has been but recently introduced and rarely tried. Its results have not been very good, but Langenbeck nevertheless thinks that what he calls the "conservative expectant" treatment should be more generally employed, because the superficial position of the bone allows free incisions and ready extraction of splinters, and the tendons do not need to be carefully preserved, since ankylosis, with the foot in a good position, should be the result sought for. Immobilization in a plaster splint is essential, with the foot at right angles to the leg, and without any deviation about its own longitudinal axis.

If conservative treatment of a gunshot fracture is determined upon, the limb must be immobilized as completely as possible, foreign bodies and detached splinters removed from the wound, and drainage secured by counter-openings if necessary. The weight of testimony is against interference with attached splinters, or the removal of the sharp ends of the principal fragments.

[1] Volkmann's Sammlung Klinischer Vorträge, Aug. 1878; quoted by MacCormac, loc. cit. p. 41.

CHAPTER III.

DISPLACEMENTS.

The relations of the two principal fragments produced by fracture of a bone may be altered in various ways, which Malgaigne classifies under six heads. This classification has been generally adopted, with the understanding, however, that a fracture usually presents a combination of two or more of them, and that there is an additional group of cases in which the number of the fragments and the character of the displacement are such as to defy classification. Under exceptional circumstances, as when the periosteum is not torn, or when the broken bone is one of a pair, displacement may be entirely lacking.

These six classes include displacements according to :—

1st. The transverse axis of the bone, *transverse* or *lateral* displacement.

2d. The long axis of the bone, *angular* displacement.

3d. The circumference of the bone, *rotatory* displacement.

4th. The length of the bone, *overriding*.

5th. Penetration of one fragment by the other, *impaction* or *crushing*.

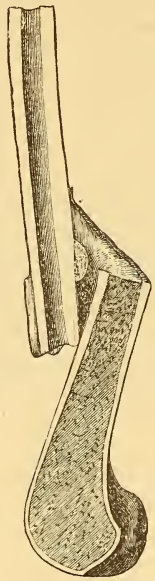
6th. *Direct longitudinal separation*.

1. *Transverse or lateral displacement* may take place forward, backward, or toward either side, and may be partial to any degree, or complete. In the latter case, that is, when the displacement equals the transverse diameter of the bone and the broken surfaces are no longer in contact with each other, the tonicity of the muscles draws the fragments past each other and adds overriding to the lateral displacement unless prevented by the presence of a collateral bone, as in the forearm or leg. Pure transverse displacement is rare, and practically may be said to occur only in transverse or dentate fractures. It is usually associated with longitudinal or angular displacement or both, as shown in figs. 30 and 31. When the bone is subcutaneous and the fracture very recent the displacement may be recognized by the eye or the finger, but when the bone is covered by thick muscles or hidden by inflammatory swelling the displacement can only be inferred from the coexistence of another. Malgaigne mentions a case in which a large clot of blood two inches above the patella was mistaken by him for the projecting end of a broken femur.

2. *Angular displacement* may vary in degree from a slight deviation, as in fig. 32, to a right angle, or even more, and may be associated with so complete and distant separation of the broken surfaces that the fragments form a T, as in figs. 34 and 35. It may sometimes be recognized by the eye, and it causes an amount of shortening which varies

directly with the degree of displacement, and the length of the shorter fragment. As has been before remarked, it is almost always found in

Fig. 30.



Transverse fracture of the femur. (Gurlt.)

Fig. 31.

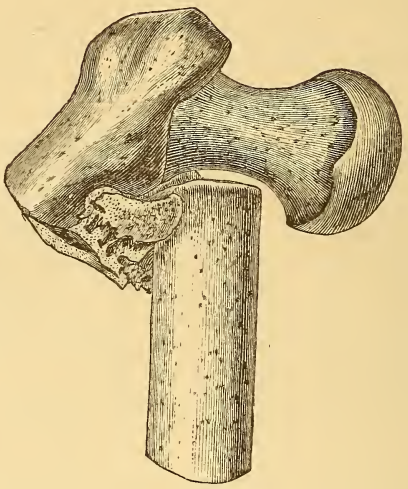
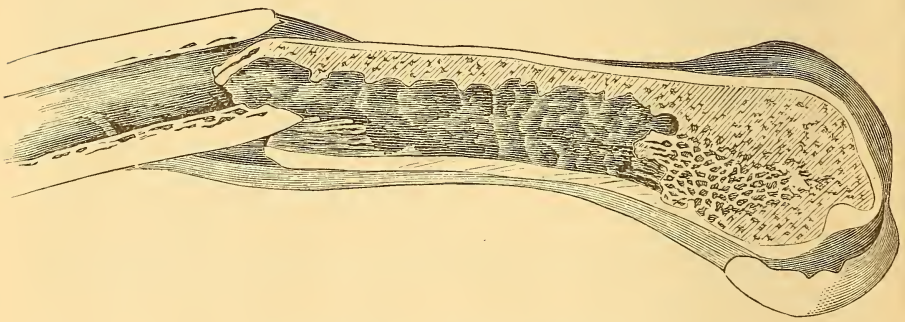


Fig. 32.

Angular displacement.

partial fractures of the shaft and sometimes cannot be entirely reduced. After complete fracture it may be produced by the unopposed action of

Fig. 33.



Toothed fracture of the tibia. (Malgaigne.)

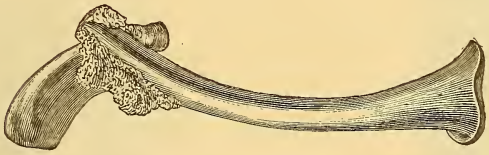
the force of gravity upon the fragments or the limb, even after splints have been applied, or by the unbalanced contraction of certain muscles or groups of muscles. As a general rule, it can be corrected by permanent extension or lateral support, except when one of the fragments is so small or so deeply placed that it cannot be properly acted on by the apparatus.

3. In *rotatory displacement* one fragment, usually the lower, turns about its long axis, while the other fragment remains in position. Thus,

Fig. 34.

Fracture of the clavicle. Union with extreme displacement.

Fig. 35.



Fracture of the clavicle.

for example, after fracture of the upper portion of the tibia the foot and lower fragment may rotate outwards, while the knee remains in position, or, more rarely, as was pointed out by Gosselin,[1] the converse may occur, and the thigh rotate outwards, while the foot and lower fragment are held in position by the splints. This form of displacement is most frequently seen after fracture near the upper articular end of a long bone, when the unsupported weight of the limb tends to rotate it about its long axis, and it is, in fact, one of the diagnostic symptoms of fracture at the neck of the femur.

Fig. 36.

Rotatory displacement after fracture of the neck of the femur.

4. *Overriding* (fig. 37) is most common after oblique fracture of the shaft, and is produced by various causes, such as the continuation for a moment after the fracture of the force that has produced it, as in a fall upon the feet, the tonicity of the muscles, or the sliding downwards of the body in the bed when the limb is fixed by a splint. It is to be recognized by the shortening which it causes, and is frequently associated with angular displacement (fig. 30). The most extreme examples are found after fracture near the end of a bone, where the shaft has split the epiphysis and passed between its fragments (fig. 38).

5. *Displacement by penetration or crushing* has been already mentioned as the impacted variety of multiple fractures (p. 57). In short bones, that is, in those composed entirely of spongy tissue without a medullary canal, there is coincident crushing of both fragments at the seat of the fracture by which an actual loss of tissue is produced and the bone is shortened and bent (fig. 39). In the long bones it occurs only at the expanded, spongy ends, and is produced by the penetration of the

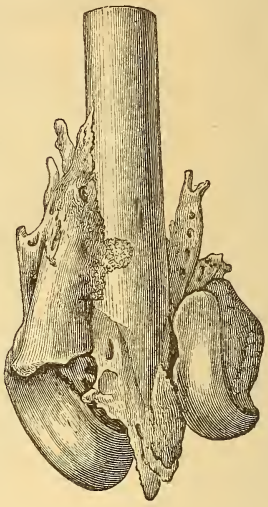
[1] Clinique Chirurgicale, vol. i. p. 270.

firmer and narrower fragments into the other, which is broader and more spongy in structure. This penetration is made possible either by the

Fig. 37.

Fracture of both bones of the leg, with overriding.

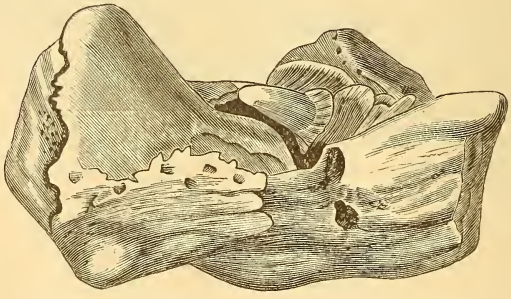
Fig. 38.



Comminuted fracture of the femur, with splitting of the condyles.

splitting of the penetrated fragment or by the crushing of its spongy tissue, as in the short bones. The accompanying figures represent these

Fig. 39.

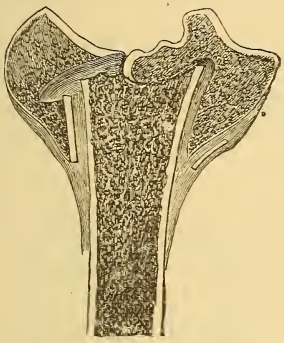


Fracture of the calcaneum, with crushing.

two varieties. Usually it is the diaphysis which penetrates the epiphysis (fig. 40), but in fracture of the neck of the femur the latter usually penetrates the great trochanter (fig. 41), in accordance with the rule that the smaller, narrower fragment penetrates the broader one. Penetration without splitting occurs only when the spongy tissue has under-

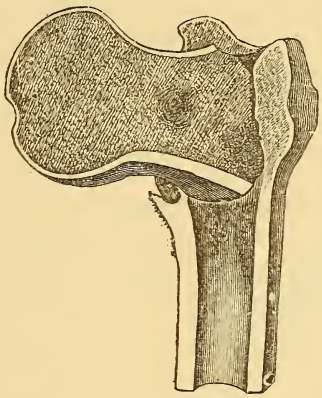
gone the senile atrophy or change characterized by enlargement of its meshes and thinning of its trabeculæ. The penetration rarely takes

Fig. 40.



Intra-articular fracture of the head of the tibia, with impaction and separation of the upper fragments.

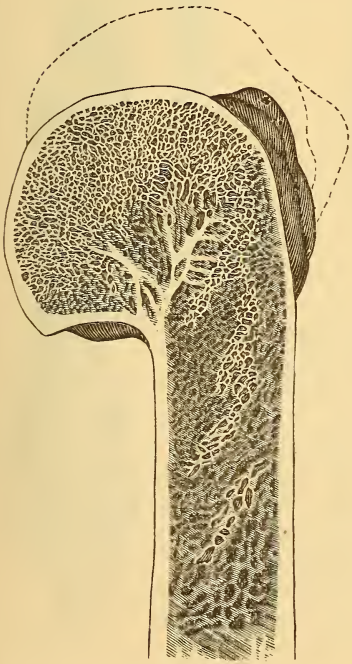
Fig. 41.



Fracture of the neck of the femur, with crushing of the spongy tissue. Vertical section.

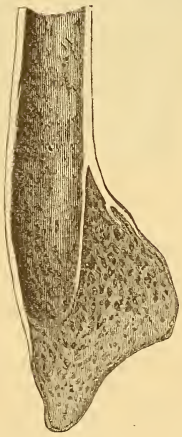
place without a change in the direction of the axes of the fragments; the resistance in the penetrated portion is greater on one side than

Fig. 42.



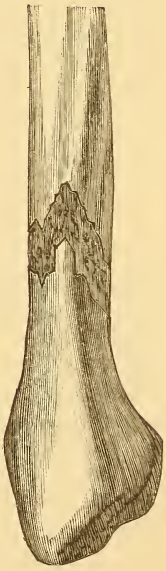
Fracture of the neck of the humerus with impaction. (Malgaigne.)

Fig. 43.



Fracture of the lower end of the radius. Angular displacement of the lower fragment backward with impaction. (R. W. Smith.)

Fig. 44.



Fracture of the fibula. Longitudinal separation.

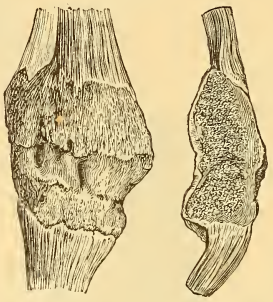
on the other, or the cortical shell of the penetrating one is thicker and firmer at one portion of its circumference than at another, so that the depth of the penetration varies and an angular displacement results; or the same effect is produced when the direction of the fracturing force is not parallel to the long axis of the bone, as in some fractures of the lower end of the radius (figs. 42, 43).

The exuberant callus found after consolidation of the fracture gives the appearance of a much deeper penetration than has actually taken place; thus, in figure 43 the triangular mass of spongy tissue on one side of the shaft is not the penetrated epiphysis, as it seems to be, but is composed in part of callus that has formed above the line of fracture.

When the impaction is in the general direction of the long axis of the bone, as at the upper end of the humerus or the lower end of the radius, the limb is shortened; but when it is nearly at right angles, as at the neck of the femur, shortening may be absent or not appreciable; crepitation and abnormal mobility are also usually lacking.

6. *Direct longitudinal separation* is seen most frequently after fracture of the patella or of an apophysis to which a powerful muscle is attached, such as the olecranon or the coronoid process of the ulna. It is also seen after fracture of either malleolus when the foot has been dislocated towards the opposite side and has carried the fragment of the tibia or fibula with it (fig. 44). Gurlt[1] speaks also of the occasional production of this displacement after fracture of the shaft of the humerus

Fig. 45.



Bony union of the patella. (Bryant.)

Fig. 46.

by the unsupported weight of the forearm and lower fragment overcoming the contraction of the muscles which usually draw the fragments closer together with overriding.

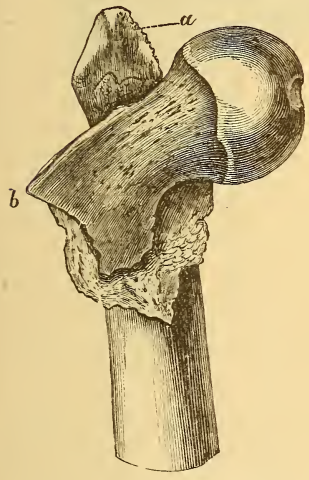
This displacement is by far most frequent after transverse fracture of the patella, and is due there to the retraction of the powerful quadriceps femoris which draws the upper fragment upward, sometimes to a distance of several inches. It can usually be recognized without difficulty by palpation, which shows the existence of a groove or sulcus of varying width between the fragments. Figures 45 and 46 represent two fractures of

[1] Loc. cit., vol. i. p. 108.

the patella in one of which bony union had taken place with moderate separation, and in the other fibrous union with wide separation.

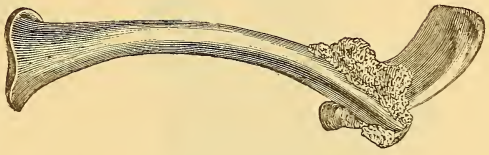
Among the *irregular* displacements, those which do not fall entirely within the above classification, may be mentioned rotation of one fragment about its transverse axis, as seen in some fractures of the neck of the humerus; in extreme cases this rotation may bring the articular surface into contact with the upper end of the lower fragment. Another is the crossing of the fragments in the form of an X (figs. 47 and 48); a third is the interposition of a bone between two fractured ones, as in fig. 49, where the astragalus is represented as having been forced

Fig. 47.



Fracture of the neck of the femur.

Fig. 48.



Fracture of the clavicle.

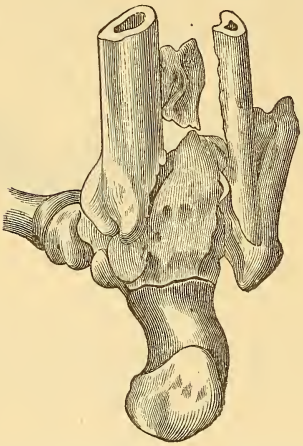
up between the tibia and fibula; and a fourth includes many comminuted fractures, especially such as the common extra-capsular fracture of the neck of the femur with splitting of the great trochanter (fig. 50), in the separation of the condyles of the same bone (fig. 38).

The character and degree of the displacement in any given case depend to a certain extent upon the direction and nature of the fracture. Thus, in a partial fracture the only displacement possible is an angular one, and in a dentate transverse fracture lateral displacement and overriding are usually prevented by the interlocking of the bony points, while on the other hand, an oblique fracture greatly favors the simultaneous occurrence of all these forms.

The active causes of displacement are of two kinds: forces external to the body, and muscular action, voluntary or involuntary. The first comprises the immediate action of the fracturing force and the prolonged action of gravity upon either fragment or the entire limb during the period of repair. Usually these displacements may be overcome, and their recurrence prevented, whenever the fragments are sufficiently large to be controlled by suitable splints, and when there is not much comminution or crushing. The displacements in impacted fractures and in most compound ones where the end of the bone projects through the skin, are produced at the moment of the fracture by the fracturing force, while most rotatory and many angular displacements are due to the gradual sagging of the limb or of a fragment. One of the most common examples is the outward rotation of the foot after fracture of the neck of the femur.

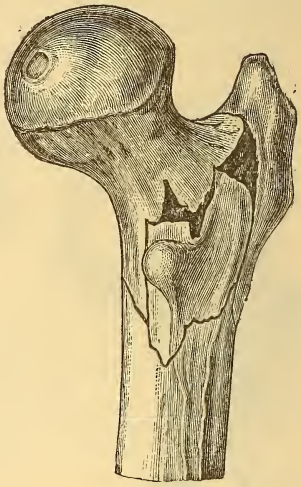
Voluntary muscular action is a cause of displacement, either at the moment when the fracture is received and the patient is in ignorance of the character of the injury, or subsequently, when he is delirious or insubordinate. Involuntary muscular action is a cause that is always ready to take advantage of an opportunity and produce overriding or

Fig. 49.



Fracture of tibia and fibula, with penetration of the astragalus between the fragments.

Fig. 50.



Comminuted fracture of the neck of the femur.

angular displacement. The pain of the fracture, and the irritation of the soft parts by the broken ends of the bones stimulate the muscles to steady permanent contraction, or excite twitchings and spasms which aggravate the pain and deformity. The traction of these muscles upon fragments which have lost their natural support either changes the relations of their axes or draws them past each other and shortens the limb. It is impossible to predict the direction and extent of the displacement by consideration of the muscles attached to the fragments. Too many other factors are involved, and experience has shown that fractures at any point may present displacements differing essentially from each other in different cases. At the same time, the effects of the contractility of the muscles are not entirely casual and irregular; the tendency to shortening of the limb by the combined action of all its muscles always exists in every case not complicated by paralysis, as does also a similar tendency to exaggeration of certain displacements produced by the fracturing cause and accompanied by free rupture of the periosteum and other soft parts. Malgaigne mentions a case of fracture of the neck of the humerus, in which the upper fragment was drawn into a position of extreme abduction by the supra-spinatus muscle after the lower fragment had been displaced far into the axilla. Lacroix[1] showed that, as a

[1] Annales de la Chirurgie Française et étrangère, 1844, vol. x. p. 257; quoted by Gurlt.

general, although not universal, rule, the displacements of the bones of the extremities formed angles which corresponded to the normal curves of these bones, which latter correspond in turn to, and are apparently due to the action of, certain groups of muscles. The influence of the muscles in most displacements by direct longitudinal separation, as after fracture of the patella, is, of course, beyond dispute.

CHAPTER IV.

ETIOLOGY OF FRACTURES.

The causes of fracture may be grouped under two heads: A. *The predisposing causes*, and B. *The immediate or determining causes.*

A. *The predisposing causes* are also of two kinds: the normal or physiological, and the pathological.

The normal or physiological causes are those which have their origin in the form, texture, and functions of the different bones, modified as they are by the changes incident to the advancing age of the individual. The statistics given at the beginning of this volume show how much more frequently the long bones are broken than the short ones; and the reasons for this difference are not obscure. The liability of a bone to fracture depends upon its power of resistance, its exposure to violence, and the opportunity which it furnishes for the more or less advantageous action of this violence. The shaft of a long bone is composed of a hollow cylinder of very firm texture, an arrangement that gives the maximum of resistance against lateral flexion and breakage with the minimum of weight. Its principal exposure is to indirect violence, to flexion or torsion, which although applied through the ends of the bone, exerts its greatest fracturing force upon the shaft, as a stick is broken by bending it.

The short bones and the expanded extremities of the long ones have a different structure corresponding to their different functions and exposure. The violence which they receive is direct, their surfaces of contact therefore are large, and their texture uniform so as to provide for a ready transmission and division of the impinging force. Their shortness, both actual and relative, as compared with their thickness, protects them almost entirely from the action of indirect violence, and their relation to the shafts of the long bones is such that the direct violence which they receive is transmitted into indirect violence exerted upon the latter. Thus in a fall from a height upon the feet the force is received upon the sole of the foot; if the limbs and back are straight and rigid, it is transmitted directly through them and causes fracture by direct impact either at the ankle, or at the base of the skull, or at an intermediate point, but if the legs are bent and the muscles tense, the bones of the leg and thigh constitute, practically, a single curved bone with its maximum of curvature near the centre just above the knee, and that then becomes the point at which the fracturing strain is greatest. Figure 51 represents the relations of the bones of the leg and thigh when the knee is flexed, and the dotted lines show the direction in which the force is transmitted. The fracturing effort is greatest at the point

where these lines cross, the point of maximum convexity in the lower third of the femur, and an additional demonstration of its character is found in the frequent projection of the lower end of the upper fragment through the skin of the anterior aspect of the thigh. The lateral and crucial ligaments, the tendon of the quadriceps femoris in front, and

Fig. 51.

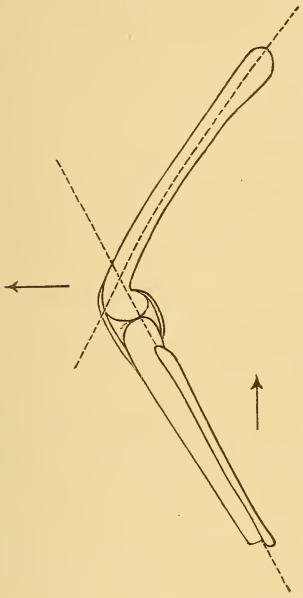


Fig. 52.

attachments of the gastrocnemii behind, fix the condyles of the femur and the head of the tibia so firmly together that they form practically a continuous bone, and, as all experience shows, fracture above or below the joint is very much more frequent than dislocation. So far as fracture is concerned, therefore, the two bones are the same as a single bone having the shape represented in fig. 52. In like manner a fall upon the palm of the hand may fracture the humerus in its lower third.

We find in the normal curves of the bones an indication of the means by which nature seeks to protect the skeleton from the effects of direct violence and which find their fullest development in flexion of the limbs and rigidity of the muscles. Every effort is made to distribute the violence and to take it up by the elasticity of the different segments, in a word, to make it indirect instead of direct, to avoid shock even at the risk of fracture. The instinct which leads a falling man to stiffen his muscles is calculated to protect his viscera at the expense of his limbs. The proverbial immunity against fracture possessed by drunkards is corroborative of this view.[1] The additional factor of a direct strain upon

[1] Two cases were recently brought into my wards at Bellevue Hospital which illustrate this fact strikingly. One had fallen while intoxicated, from a fourth-story window, and sustained no injury except contusions; the other had fallen while asleep

the bone, by the contraction of the attached muscles will be discussed when we come to consider the direct influence of muscular action in the production of fractures.

The position and functions of the extremities, especially the forearm and leg, also expose them to fracture to a degree far exceeding that of the bones of the trunk; they are, as it were, outlying members, which are the first to receive the shock in a fall, they are often interposed to protect the head or body, they come into close relations with machinery, and are more frequently caught by falling bodies or moving wagons.

The greater relative frequency of fracture in people over fifty-five or sixty years of age has been already mentioned. The cause was long supposed to lie in the presence of lime-salts in the bones of old people in larger proportion than in those of the young, but more recent investigations have shown that the assumption upon which this explanation is based is incorrect. The proportions of organic and inorganic matter in the bone tissue itself do not change as supposed, and the real cause of the greater brittleness in advanced life is the actual diminution which then takes place in the amount of the bone substance. The external dimensions remain unchanged, but all the cavities increase in size by absorption of their walls, and become filled with fat so that the bone will almost float in water. The cylindrical shell of the shaft is so thinned in extreme cases that a very slight force is sufficient to break it, and the spongy tissue is similarly weakened by the disappearance of many of its trabeculæ, and the consequent enlargement of its meshes. This change is known as senile or interstitial atrophy, and is always present to a greater or less degree in advanced life. It is this weakening, this inability to withstand direct violence, that explains the especial frequency of certain fractures—notably those of the neck of the femur and impaction at the upper end of the humerus, or at the lower end of the radius. A stumble or misstep is often sufficient to fracture the neck of the femur in an old person, as is also a slight fall upon the knee or the great trochanter.

In young children, whose epiphyses are almost entirely cartilaginous, the elasticity of this tissue is thought by Gurlt to be a protection against fracture of the shaft by indirect violence, but fractures are by no means so rare among them as to require such a purely hypothetical explanation of their rarity. They present the usual varieties of fracture, with a relative predominance of the incomplete or partial ones, and, as a rule, with much less displacement than is found in later life. This last fact is to be explained, in part at least, by the greater thickness of the periosteum.

While atrophy is usually so moderate in degree and so widespread in its distribution, when it presents itself as a senile change, that it may be considered with propriety among the normal or physiological predispositions to fracture, yet when it appears prematurely, or reaches an ex-

from the roof of a four-story house and received a severe injury of the back and a contusion of the foot, but had broken no bones except possibly one of the vertebræ. The former recovered promptly, the latter died of septicæmia originating in gangrenous emphysema of the bruised foot, a dissection of which showed the absence of fracture.

treme degree, it is the result of something more than the usual senile wasting, and must be classed as pathological, together with other atrophies which show similar gross pathological changes, but whose nature and causes are far from being thoroughly understood. In the same connection may be mentioned cases of inherited congenital and developed liability to fracture, in which, as direct examination of the bones was not made, there is no knowledge of the accompanying anatomical conditions. Of the inherited liability Gurlt gives three examples, extending in one case over four generations, in the others over three each. The following is a condensed report of one case :[1]—

First Generation.—A woman had suffered five fractures of the left and one of the right thigh, caused by slight violence, and preceded in the last case by severe pain in the limb. Her brother broke one thigh twice, the other nine times, the arm twice, and dislocated his hip once—all before he was thirteen years old.

Second Generation.—The son of the woman had fourteen fractures before he reached the same age (thirteen years). The first was a fracture of the femur caused by a fall from a step six inches high, and united in five weeks; four months later the forearm was broken by a fall from a chair; after another four months, fracture of the ulna by a wrench of the arm, united in three weeks; again, four months later, fracture of the humerus, radius, and tibia on the right side, by a fall down two steps, about eleven inches; all united in less than four weeks. Afterwards six fractures of different bones.

He gives also three cases of a congenital but not inherited disposition to frequent fracture in the children of a family. In the first case three brothers were affected. The eldest suffered only one fracture, that of his right thigh, when he was three years old; the second brother had four, and the third had nine fractures between their second and nineteenth years. With two exceptions the fractures were caused by moderate external violence; they all united in four or five weeks, and caused deformity in only two cases. The liability disappeared as the patients advanced in years.

In the second reported case a healthy but rather delicate girl suffered thirty-one fractures between the ages of three and fourteen years; the right thigh seven times, the left once; the right leg nine times, the left once; the right arm four times, the left three times; and the left forearm once. They all united rapidly and easily. Her sister, six years old, had suffered nine fractures, the first at the age of eight months. No similar predisposition existed in the parents, nor in the two brothers and a third sister.

Gurlt admits his inability to find a sufficient explanation of the disposition manifested in these cases, for neither parents nor children presented any recognizable cachexia or defective structure of the bones; he places it, therefore, with that other obscure tendency, the hemorrhagic diathesis, among the problems whose solution requires many more detailed observations.

[1] Gibson, Institutes and Practice of Surgery, 7th ed., 1845, vol. i. p. 237; quoted by Gurlt.

The cases in which individuals have developed in early or middle life a noticeable fragility of the bones without known cause are not very rare. Gurlt has collected seventeen such, characterized not only by the remarkable facility with which the fractures were produced, but also by an exceptionally rapid and easy recovery. He is unwilling to believe that in them, or in the preceding cases, the fragility was due to atrophy of the bone, because the majority of the individuals were reasonably well and strong, and did not show signs of that atrophy of the soft parts which has always accompanied atrophy of bone in cases where the latter condition has been verified by examination.

The pathological condition known as general atrophy or rarefaction of the bone, or osteoporosis, and which has been referred to as senile atrophy, may appear prematurely, or may have its origin in other causes than senility—such as paralysis, locomotor ataxy, or osteomalacia. It is worthy of note, that in not a small proportion of the cases (excluding the ordinary fractures of the neck of the femur) union takes place easily and rather promptly. In most of the cases that furnish autopsies the bones are found softened and reduced to a shell by absorption from the inside, and in some of the cases suppuration has taken place at the fracture, and death has followed with symptoms of purulent absorption. The following cases, quoted from Gurlt, represent the different varieties.

A woman, seventy-two years old, had both thighs broken by kneeling in church, and the humerus by the efforts of the bystanders to lift her up. Another broke her collar-bone by putting her arm about the nurse's neck, and trying to turn herself in bed.

A weakly boy, with healthy parents, brothers, and sisters, began at eight months to suffer with boils (or cold abscesses) followed by extensive ulcerations, probably lupus, at the nose and ears. He had then six different fractures, which suppurated and caused his death at the age of $2\frac{1}{2}$ years. The fractures involved the humerus, femur, both bones of the leg and forearm, and had not united. The bones were small, unusually spongy near the fractures, and could be easily cut with a knife, but were hard and rigid. The viscera were healthy.

A woman, forty-five years old, the mother of two children, suffered a great deal of pain in her bones after the birth of the second child, and became so helpless that she could not get into or out of bed without aid. She broke both thighs below the trochanters by stumbling against the bed-post in one case, and by turning in bed in the other. Both united with marked angular displacement, and at the autopsy the bones of the thigh and pelvis were found to be so light that they floated in water and could be crushed by pressure with the finger. The cortical substance of the femur was as thin as an egg-shell, the medullary canal enlarged, traversed here and there by delicate plates of bone, and filled with a grumous, semi-fluid mixture of blood and marrow.

A woman, twenty five years old, began to suffer pain in all her limbs, especially the thighs, became bedridden, and died four days after she had broken her left thigh by turning in bed. The bones were of normal size, lighter than usual, and could be easily broken, with comminution and escape of much blood. The periosteum was loosely adherent, the bones dark red and full of blood; the cortical layer of the femur was

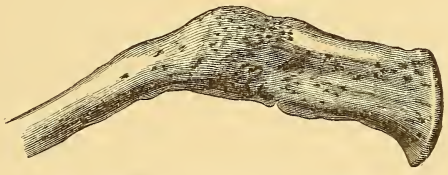
only one line in thickness, and the canal was filled with a thick, dark red marrow. The neck of each femur was completely absorbed.

A man, fifty-six years old, bedridden for many years, had both thighs broken while being turned in bed. Firm union followed. After death the bones were found atrophied and softened.

Saviard saw in 1690 at the Hôtel Dieu, in Paris, a woman about thirty years old who had suffered for four months with severe pains throughout the body, increased by movements and without fever. Three months later she had become bedridden, and her bones had grown so friable that most of them were broken, and she could not be moved without causing a new fracture. She lived ten months in this condition, and the autopsy showed fractures of almost every bone in the body. Their structure was so delicate that they could not be pressed between the fingers without breaking into small pieces; the marrow was red, the muscles pale, the joints and cartilages unchanged.

A woman, fifty-nine years old, with complaint of wandering pains, œdema, albuminous urine, fibrinous casts. Pains in the spinal column with gradual curvature; pain in the first and second sterno-costal joints with swelling; fracture of the right clavicle near the sternal end without known cause; lime salts abundant in the urine; union of the fracture in twenty-three days. Three months afterwards, while turning in bed, fracture of the left clavicle at the corresponding point; two days later fracture of the right femur three inches above the condyles by sitting up in bed and allowing the legs to hang over the side. Death six days afterwards. All the bones showed atrophy of the cortical layer and enlargement of the meshes of the spongy portion; complete firm union of the left (?) clavicle (fig. 53); the ribs all bent and showing twelve

Fig. 53.



United fracture of the clavicle. Osteomalacia.

to fourteen fractures united with exuberant callus, but so friable that they could be broken by pressure between two fingers; the vertebræ were as soft as gelatine, the pelvis normal in shape.

Benjamin Bell[1] reports a case where only one bone was affected, and in which the pathological changes were different. He gives no intimation of the cause. "A gentleman at the middle period of life who fractured his humerus in unscrewing a music-stool. The fracture was comminuted and did not unite. Several months afterwards the arm was amputated by my father, Mr. George Bell, at the shoulder-joint. On examining the limb the muscles surrounding the fractured bone were found to be in a pulpy state. A quantity of partly fluid and partly coagulated blood

[1] Diseases of the Bones, 1828, p. 72.

enveloped the bone, which was fractured near its centre. Several fragments of bone, varying from one to three inches in length, lay imbedded in the blood. No attempt at the adhesive or reparative inflammation seemed to have been made. The bone was almost friable, and its outer surface, from the neck of the humerus to the condyles, was perforated by innumerable small, irregular-shaped holes, giving to the bone, when macerated, a true reticulated appearance; and this peculiar reticulated appearance was also observable in the osseous plates of the cancelli."

In the following case, that came under my care in 1880, the bone appears to have been weakened by a blow and a wound of the soft parts received about five weeks before. The patient was a healthy man, thirty-five years old, who was admitted to the Presbyterian Hospital with a lacerated wound across the front of the middle third of the left leg, caused by the fall of a stone. The wound healed in three weeks and he left the hospital. A fortnight later, Nov. 4, 1880, he returned with a compound fracture at the scar, caused by stepping down from a window-sill to the ground, a distance of two feet. He had had no pain in the leg previously. The bone could be seen plainly and was rarefied and soft; the fracture seemed to be transverse, and with but slight displacement. Recovery followed promptly.

A similar friability is also found in some cases of old unreduced dislocation, due, it is supposed, to lack of use. This fact should always be borne in mind when an attempt is made to correct such a condition. Malgaigne thinks the danger of fracture exists only when the bone has been the seat of dull pain, and attributes it to a local inflammation; but this opinion is hardly in harmony with all the reported facts. Prof. Markoe[1] reports a case of dislocation of the hip of seven weeks' standing, in which he fractured the femur while attempting reduction without apparatus and employing only a "slight amount of force." He repeats the same warning that the greatest care must be taken "in using bones which have long been disused, as levers in reducing displacements."

Disease of the Nerve-centres.—In 1842 Davey called attention to the facility with which fracture sometimes occurred in lunatics, especially in those who were also paralytic, and the observation has been abundantly confirmed, Burns (*vide infra*) having collected more than sixty reported cases. Weir Mitchell[2] was the first to call attention to the frequency of fracture in those affected with locomotor ataxy, and suggested that the cause might lie in an impairment of the nutrition, and consequently of the strength, of the bone dependent upon the disease of the cord. Shortly afterwards Charcot[3] published a remarkable case of multiple "spontaneous" fractures and dislocations in an ataxic woman, and very recently Burns[4] has published a paper upon the subject based upon thirty cases reported within a few years. He finds that the fractures are usually multiple, from two to six in number, and are most common in the lower extremity, especially in the femur; the frequency is equal in the different bones of the upper extremity—clavicle, humerus, and forearm.

[1] Diseases of the Bones, p. 18.
[2] Am. Journal Med. Sci., July, 1873, p. 113.
[3] Archives de Physiologie, 1874, p. 166.
[4] Berliner Klin. Wochenschrift, 1882, p. 164.

Repair takes place in the usual time or in less, and the callus is sometimes exuberant.

The accident seems to occur more frequently in the earlier than in the later stages of the nervous disease, and its predisposing cause is a rarefaction of the bone marked by great absorption of the compact tissue, increase of fat, and loss of inorganic matter. It is not improbable that in some of the cases reported by the older writers and quoted above, especially in those in which pain is mentioned as a preliminary symptom, the patients were ataxic.

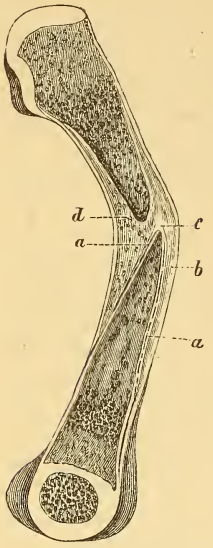
Rachitis.—Friability due to rachitis is found only in childhood, for the disease is one which involves the bones only during their period of growth, and consists essentially in the prolongation and exaggeration of the embryonal or developmental condition of the shaft. The layer of tissue known as chondroid (Broca), or spongoid (Guérin), by means of which a bone grows in length, and which is intermediate between the shaft and the epiphysis of a growing bone, and is normally only a line or two in thickness, becomes in a rachitic bone very much thicker and continuous with a thick subperiosteal layer of similar tissue covering the entire shaft. The cylindrical shell of the shaft presents, instead of a solid, uniform, bony wall, a series of alternating layers of fully formed bone and the above-mentioned spongoid tissue, or there may be a thin compact shell adjoining the medullary canal and covered externally by a thick layer of this softer, incomplete, or embryonal bone. The disease is common among children of the poorer class, and those affected by it furnish, according to Guersant, about one-third of all fractures at that age.

The spongoid tissue is composed of modified cartilage infiltrated with an abundance of lime-salts, and containing only a little real bone arranged in irregular lamellæ or patches; it is more soft and friable than normal bone, more easily crushed or broken, and the most frequent form is the partial or incomplete fracture, impaction, with the fracture on the concave size of the bend. As the age of the individual increases, the bones acquire the normal structure, and their solidity is then as great as or even greater than it is under ordinary circumstances, because of their increased thickness. There is no lack of examples of rachitic fractures in foreign records, but the affection seems to be much rarer here. Malgaigne saw a rachitic child that had suffered four fractures (one of the humerus, three of the femur), between the ages of six and ten years, and quotes another from Jacquemille of six fractures (arms and thighs) between the ages of twelve and thirty-two years. In this latter patient apparently the rachitis had persisted much longer than usual. In the Dupuytren Museum at Paris is the skeleton of a rachitic child, six or seven years old, showing twelve fractures. Lonsdale has reported one with twenty-two fractures, and in the London Medical Gazette (1833) is the account of another with thirty-one. Esquirol's famous case, mentioned in most works upon fractures, was a rachitic woman whose skeleton showed more than two hundred fractures, all more or less well united.[1]

Union takes place rather more slowly than in normal bone, and sometimes fails entirely. The callus is usually large, but as it is composed

[1] Malgaigne, Fractures et Luxations, vol. i. p. 20.

Fig. 54.



United fracture of rachitic femur. (Gurlt.)

of the same soft embryonal tissue whose excess is the pathological feature of the disease it is lacking in firmness. Fig. 54 shows how the medullary canal may be obliterated even in incomplete fracture by the bending in of one of its sides, and also how the callus tends to straighten the outline of the bone by filling up the hollow of the angular displacement.

Syphilis, Mercurialism, and "Rheumatism."—Syphilis affects the organism in so many and so varied forms, and causes such serious bone lesions in its later stages, that it is not strange that both physicians and patients have been inclined to attribute to it fractures produced by slight causes whenever the patient was or had been affected by it. And in like manner those who saw in mercury the cause of the bone lesions of syphilis attributed the fractures to the use of that drug.

When we remember what multitudes of people have contracted syphilis, how numerous those in whom it has caused grave lesions of the bones, and on the other hand how few are the cases in which it can even be suspected as a predisposing cause of fracture, it is evident that it has but little, if any, influence in this direction; and an examination of the alleged cases shows very frequently a coexistent constitutional weakness or a cachexia not always to be attributed to the specific disease, which creates a close resemblance between these cases and those in which the friability of the bone is due to a premature or exaggerated senile atrophy. The pathological anatomy of syphilis, too, does not show any morbid change produced in bones by this disease which would markedly increase their friability, although there are some specimens of hyperostosis, of general enlargement of the shaft of a long bone, accompanied by such a rarefaction of the tissue that the strength of the bone is lessened, notwithstanding its enlargement. I have one such specimen in which the lower third of the femur is nearly doubled in diameter, while its wall is much thinned and abnormally porous. It is of course possible that this rarefaction may exist without hyperostosis or actual increase in size, and the strength of the bone be notably diminished thereby, but there is no proof of it, if we except the caries sicca of the cranial bones, a process marked by absorption of the bony tissue about the minute canals and under the periosteum, and consequent production of depressions on the surface or of perforations, some of which may extend entirely through the bone.[1]

In only two of the fifteen cases collected by Gurlt[2] in which fractures were produced by slight causes in syphilitic individuals were the bones examined; in one of them after death, in the other incidentally to an operation for pseudarthrosis. Of the former it is stated only that the

[1] Compare Keyes, Venereal Diseases, 1880, p. 186.
[2] Loc cit., p. 179.

bones were very friable; of the latter it is said the pieces removed were soft and friable, and the medullary canal enlarged with notable thinning of its wall and a great excess of fat. In one case the humerus was broken two or three times and the clavicle twice, in the other the femur once by slight causes; both patients were of delicate constitution, and one of them died, apparently of phthisis, at the age of 27. They cannot be said to prove anything in this connection.

It seems not improbable, on general grounds, that syphilitic pain in the bones may be the result of pressure within the Haversian canals or under the periosteum, and that this pressure if not relieved may result, as it does under other circumstances, in an enlargement of the affected canals by absorption of their walls, in other words, in rarefaction of the bone and consequent diminution of its strength, just as in general atrophy. Gurlt's fifteen cases include five in which the fracture was preceded by severe pain, more or less prolonged, in the broken bone, and these might be considered as demonstrative of the influence of syphilis did we not possess other similar cases in which the syphilitic complication does not exist. Malgaigne,[1] indeed, speaks of local inflammation of the bone as a frequent and too much neglected predisposing cause of fracture, adding: "I give this name, conjecturally, to an affection which generally manifests itself by dull pains attributed by the patient to some contusion or to rheumatism, rarely sufficient to cause a general reaction, and attracting but little attention until some slight cause produces fracture at the point it occupies." There is a striking similarity between the cases he cites in this direction and Gurlt's syphilitic cases.

"*Rheumatic*" *Cases.*—A carpenter's apprentice suffered for a month with rather severe rheumatic pains in the left arm, and then broke it by pressing firmly upon the handle of a centre-bit, which he was turning with his right hand.

A laborer broke his right arm by throwing a stone. He had always been healthy, but during the preceding month he had been suffering from pain in this arm which had increased to such a degree that he had stopped work.

A strong well-built youth of 20 years broke his femur by a fall upon the ground while walking; for a few weeks previous to the accident the limb had been the seat of pains supposed to be rheumatic.

Syphilitic Cases.—A woman, 40 years old, had pain at night for a year in the middle of the arm, and then broke it at the affected point, without violence. On examination a perforating ulcer was found on her soft palate; the fracture healed in seven weeks under anti-syphilitic treatment, and a year later she presented herself with nodes on the left femur.

A soldier suffered for a long time with nightly osteocopic pains in the right humerus, accompanied by fever and loss of flesh, and relieved by baths and mercurial inunctions. During slight salivation produced by the internal administration of the bichloride of mercury, and while the pain was still diminishing, he broke the arm in the middle by trying to

[1] Loc cit., p. 22.

turn upon his right side. An "exostosis" was found extending from the elbow to the seat of fracture. Union took place within a month.

A man of delicate constitution had a chancre and two buboes in 1814, followed by ulcers in the neck and pain in the bones. In 1816 he was treated twice in Berlin by inunctions, which reduced his strength greatly, but did not relieve his symptoms. His right arm, which had long been the seat of severe and constant pain, was then broken by slight violence, and the fracture did not unite. In 1818, being in a very wretched condition, he consulted Delpech, and was placed upon a tonic treatment, during which the fracture seemed to unite, but after a somewhat violent movement one day a new fracture was found two inches below the first. Sometime afterwards, the tonic treatment having been kept up meanwhile, Delpech cut down upon the bone, found the upper fracture united by a pliable callus, and the lower one without a trace of union; he removed at different times about three inches of the bone, which was soft and fragile, with thin walls and full of fat, and obtained fibrous union. Under mercurial and tonic treatment the syphilitic symptoms disappeared, but the left clavicle became the seat of severe pain and was broken in the centre by the effort made in putting on a vest; this fracture united solidly, and was followed by another at the sternal end of the same bone, also preceded by severe pain.

An apothecary,[1] 38 years old, broke his right humerus while drawing a tooth. For a year previously he had suffered more or less with pain at the seat of the subsequent fracture, and the bone had seemed so weak that he feared to use it, although it had increased greatly in thickness. He had also pains at night in his head and joints, and nodes upon the skull, and was taking the iodide of potassium. The fracture united promptly, but the arm remained useless.

There seems to be no reason to suppose that mercury has any direct action upon the bones, rendering them more liable to fracture, and the most that can be claimed, is that its excessive, unskilful use will cause a general deterioration of the health, which may result in an atrophy of the bones, similar to that found in old age and in some paralytic conditions.

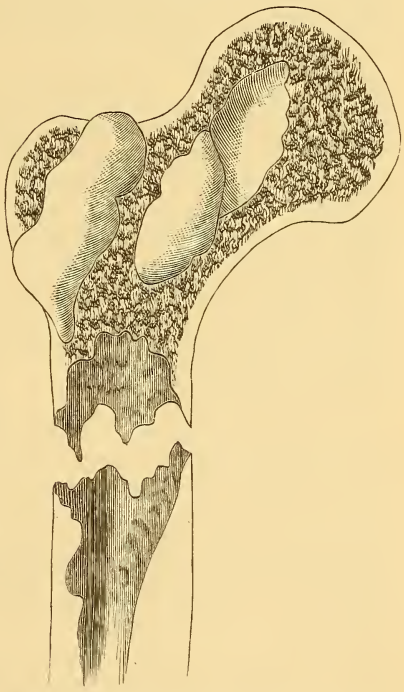
Cancer.—There are two ways, apparently, in which the development of a cancer may lead to fracture of one or more bones: either the tumor may occupy the bone itself, primarily or secondarily, and destroy it to such an extent that the slightest force is sufficient to fracture it, or the presence of the tumor elsewhere may induce a cachexia which results in an atrophy of the bone similar to that found in the senile condition. The first stage of the development of a cancer in bone presents the changes of rarefying osteitis with substitution of granulation or fibrous tissue for the bone, the cancer cells then develop in this new tissue, as they do in fibrous tissue elsewhere. In a case of extensive generalization of cancer which came under my observation, portions of several ribs and vertebræ, a large part of the pelvis, and the upper portion of the right femur were so changed in texture, although their external form

[1] W. Parker, in N. Y. Journ. of Med., July, 1852.

was perfectly preserved, that a knife could be easily thrust through them. Under other circumstances the morbid growth seems to localize itself in the medullary canal, and to destroy the cortical layer by absorption; when the latter is reduced to a thin shell, a very slight effort may fracture it. This occurred also in the case to which reference has just been made. The right femur was broken at the junction of the lower and middle thirds, by the patient turning in bed about a fortnight before his death. The external dimensions of the bone were unaltered at the seat of fracture, but it was reduced to a shell not more than a line in thickness, and its interior was filled by a mass of soft pink tissue, which extended two or three inches along the medullary canal on either side of the fracture, widening it, and even perforating its wall in places.

When the tumor is sufficiently large to be easily recognized from without, and to clearly account for the fracture, even if not to cause it to be anticipated, we should look upon the fracture as an accident or epi-phenomenon of the tumor, rather than regard the tumor as a predisposing cause of fracture; but in the other class of cases, where the presence of the morbid change in the bone is not recognizable, when the fracture occurs without any warning, and is the first thing that calls attention to the bone, or even, as in Louis's case, first brings to the surgeon's knowledge the existence of a cancer at another point, we may certainly class it with the other constitutional predispositions. Gurlt[1] collected thirty-eight cases of this latter kind, of which the following may serve as examples of the different varieties, modes of termination, and possibility of reunion.

Fig. 55.



Cancer of the femur—Fracture. (Cruveilhier.)

Louis[2] was called to see a nun, sixty years of age, whose arm had been broken by the efforts of a coachman to help her into a carriage. Union did not take place, and six months afterwards, while seated in a chair, she broke her femur by letting her hand fall upon it. Louis, seeking the cause of this fragility, then learned, for the first time, that the patient had an ulcerated cancer of the breast.

A woman,[3] forty years of age, who had a cancer of the breast

[1] Loc. Cit., p. 184.
[2] Quoted also by Malgaigne, vol. i. p. 14.
[3] Cruveilhier's Anat. Path. Livraison XX. Pl. I. fig. 4.

for some time, with well-marked cachexia, broke her right femur in the lower third by rising from a chair. She was taken to the hospital, and there the other femur was broken by the interne as he was preparing to apply a bandage to the first. She died the same night, and at the autopsy cancerous masses were found in the spongy tissue and in the medullary canal at the points of fracture and elsewhere (fig. 55), also in the vertebræ and cranial bones.

A woman, thirty-four years old, had an encephaloid tumor in the left axilla. She broke her left humerus with an audible snap by pressing against the side of the bed, and died three days afterwards. At the autopsy two ribs were found fractured, in addition to the humerus, and numerous cancerous nodules were scattered over the peritoneum, costal pleura, ribs, and abdominal viscera. There was no sign of any heterologous growth in the broken humerus, and the other humerus was not brittle.

A woman,[1] forty-nine years old, with tumors under the lower jaw, in both breasts, the uterus, and other organs, broke her right humerus while washing one of her children, then her left humerus while cutting a piece of bread, then the clavicle by throwing a book out of bed, then the right humerus again by rising in bed, and the left humerus again by tearing the burning clothing off a child. All the fractures united readily, with abundant callus.

A woman, fifty-two years old, with ulcerated cancer of the breast, had her humerus broken by the efforts of the nurse to raise her in bed. Good union apparently in six weeks; death by exhaustion in ten weeks. On inspection the fracture appeared to be healed, but on sawing the bone longitudinally, the broken ends were found unaltered in appearance in thickness, and inclosed in a rather thin bony ring. A mass of fibrous tissue, in which were imbedded numerous smaller masses, composed entirely of cancer-cells, filled the medullary canal at the seat of fracture, and similar small cancerous masses were found at other points of the canal. The cortical layer of the bone was eroded at points corresponding to the cancerous nodules, and in some places even perforated. Cancerous nodules in the liver.

A woman, forty-seven years old, broke her femur just below the trochanters by getting out of a wagon, fifteen months after a cancer of the breast had been removed by operation. Union took place in six weeks, and she died nine months afterwards of exhaustion. The autopsy showed that the upper portion of the femur had been changed into a large meshed network, with tenacious dirty-gray contents. The fracture had followed the intertrochanteric line, and the union had been accomplished by interlacing spiculæ of bone passing from one fragment to the other.

Of thirty-two of these cases in which the position of the primary tumor is noted, it occupied the mammary gland twenty-six times (once in a man); and of the entire thirty-eight cases thirty-five were women. As a rule, too, the affection was of long standing; in many of the cases the tumor had returned after removal, and in nine it had ulcerated.

[1] Lancet, April 8, 1837.

The humerus and femur were almost exclusively affected, but in very unequal proportions—twenty-six fractures of the femur and seven of the humerus. Severe localized pain in the bone preceded the fracture in a number of cases.

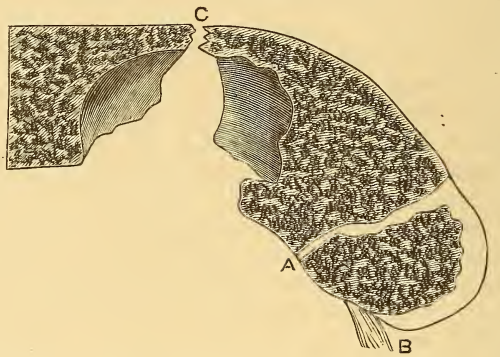
Reunion took place in one-fourth of the cases, and in at least three of these there was cancerous degeneration of the bone at the seat of the fracture. In most of the remaining twenty-eight cases death, due to the progress of the disease, followed so soon after the accident that the bones had not time to unite, even if they were capable of carrying on the necessary processes. There is no reason to doubt the probability of reunion in cases where the recurrence of fracture has been favored by simple atrophy, for such reunion is the rule in other cases where similar atrophy has been induced by other causes; but when the predisposing cause has been absorption of the bone by the growth of a cancerous mass within it, not only does the subsequent growth of the tumor, which is all the more rapid in consequence of the relief of pressure, continue the work of destruction, but the mass itself constitutes a mechanical obstacle to union by its interposition between the fragments, and, in addition, the destruction of the marrow and the reduction of the bone to a mere shell remove the two principal elements by which the process of repair is normally carried on. In the ossifying forms of cancer it is possible that trabeculæ starting from either end may unite with one another, and thus bind the fragments together, as occurred possibly in the last case mentioned above.

Hydatid and other Cysts; Caries and Necrosis.—There are a few instances on record in which the unsuspected development of a hydatid cyst within a bone has resulted in its fracture by slight violence at the point occupied by the cyst; and others in which a similar result has been produced by the occurrence of a cystic degeneration of unspecified character within the bone. These causes act by direct absorption of the cortical layer of the bone, not by a modification of its structure, and their effects are confined to the single bone and the single point involved by the disease. Facts of this kind deserve mention in this connection only on account of their resemblance to other cases in these respects, that the fracture is produced by slight violence, and no warning is given by change in the volume or functions of the limb.

While caries and necrosis are among the most common of diseases, and often cause a very considerable loss of substance, Gurlt says the examples of fracture during the existence of either condition are exceedingly rare. The reasons are apparently of two kinds: the disease is in itself of sufficient importance to require the affected limb to be kept more or less completely at rest, and thus withdrawn from exposure to the usual immediate causes of fracture; and, secondly, the process is either accompanied by compensatory ones which strengthen the bone by forming new tissue in the place of that which is destroyed, or it affects the short bones or the spongy ends of the long ones, which, as has been shown, are the least liable to be broken. When the shaft of a long bone becomes necrosed in whole or in part in consequence of an acute periostitis, or osteo-myelitis, the dead bone retains, not only its firmness, but also its connection with the living portions until an involucrum has been formed

about it, and this involucrum is ordinarily sufficiently large to resist effectually any fracturing violence to which it may be accidentally exposed. The chronic carious process often lasts for years without causing much loss of substance, and the bone is strengthened by condensation, eburnation, of the parts adjoining the cavity ; but when the process is more rapid, and the loss of substance is greater, involving almost the entire thickness of the shaft, fracture is likely to be caused if the limb is not handled with great care. Fig. 56 represents the lower end of a femur

Fig. 56.



Fracture of carious femur. A. Epiphyseal cartilage. B. Crucial ligament. C. Point of fracture.

removed by amputation after fracture in a case which came under my observation in 1877. The patient was a lad of twelve years, who had been affected for some time with suppurative disease in the right femur and tibia ; a fistulous opening above the knee led to bare bone, and an operation was undertaken for its removal. After the bone had been exposed, and two small necrosed fragments removed, the surgeon tried to straighten the partly flexed leg, without using much force, however. A sharp crack was heard, and it was found that the bone had been broken. The figure shows that the lower fragment had been so bent by the prolonged flexion of the knee and the traction of the posterior muscles of the thigh, that its articular surface was directed rather backwards than downwards.

B. Immediate or Determining Causes of Fracture.

These exist in every case of fracture, for a bone breaks only when the strain to which it is subjected is superior to its power of resistance. It is entirely immaterial whether this strain or this power of resistance is great or small, and therefore the term *spontaneous*, which is sometimes applied to fractures produced by very slight violence, such as turning in bed, ought to be abandoned, for it does not properly express the idea which it is intended to convey.

The immediate cause of a fracture may be either a force acting from outside the body, as in a blow or a fall, or one originating within the body, and exerted directly upon the bone which is fractured by the

action of muscles attached to or closely connected with it. Those produced by the first cause are called fractures by external violence; those by the latter, fractures by muscular action.

a. Fractures by external violence. The division of these into two classes, of which one is called fractures by *direct*, the other fractures by *indirect* violence, is based upon clinical differences often of extreme importance, and not simply upon mechanical differences in the mode of transmission and in the effect of the applied force. This relieves us, therefore, from the necessity of examining into the latter questions with their many obscure factors and complex relations, and makes the definitions simple. A fracture by *direct violence* is one, surgically speaking, in which the bone is broken immediately under the point upon the surface where the fracturing violence is received; and a fracture by *indirect violence* is one in which the fracture takes place at a distance from that point. Thus, a fracture of the leg by a blow with a heavy bar, by the passage across it of a wheel, or by the impact of a rifle-ball, is a fracture by direct violence, while a fracture of the thigh by a fall upon the feet, or of the clavicle or humerus by a fall upon the hand, is a fracture by indirect violence. The most important clinical difference between the two varieties depends upon the injury to the overlying soft parts in the one case, and the absence of such injury in the other, upon the probability that in the former the fracture will be compound, and will suppurate on account of the bruising and subsequent sloughing of the soft parts, and that in the other it will be simple, or if compound may not suppurate, and may run the course of a simple one. In addition, fractures by direct violence are more likely to be comminuted and to be accompanied by serious injury to adjoining vessels and nerves, which may necessitate amputation.

It is worthy of remark that the skin is not always broken in fractures by direct violence, even when the vulnerant force has been extreme and the injury to the soft parts under the skin very extensive. The toughness and elasticity of the skin sometimes preserve it, especially when the body that exerts the violence acts over a large surface, and does not present sharp angles or edges. The passage of the wheel of a heavily laden wagon across the leg may crush both bones into splinters and reduce the muscles to a pulp without breaking or even apparently injuring the skin. On the other hand, the blow may break the skin at the point where it is received and produce fracture by indirect violence at a greater or less distance, the bone yielding at its point of least resistance, and not at that where the force is directly exerted.

The fracturing force may be applied *directly* or *indirectly* to the bone (causing compression, splitting, or penetration), or obliquely to its long axis, or as torsion, or as avulsion. Examples of the *first* are furnished by falls upon the feet with fracture of the calcaneum, gunshot wounds, impacted fracture of the lower end of the radius or of the upper end of the humerus with penetration of the epiphysis by the hard shell of the shaft, of the second by most fractures of the shafts of long bones, of the third by some fractures of the leg where the foot is fixed and the body turned forcibly about it, and by others in which the fracturing force is due wholly or in part to the action of muscles attached to the side of the

bone and exerted in a plane that is not parallel to its axis, and of the fourth by fracture of either malleolus by lateral displacement of the foot. The mechanism in direct fractures produced by falls or by blows is the same, for from a mechanical point of view it is indifferent whether the force is developed by the movement of the limb or of the external object with which it comes into contact.

Indirect fractures are by far more common in long bones than in short ones for reasons that have been considered already in the section on form and function considered as predisposing causes of fracture. The principle of their production, which was also mentioned in the same section, is that of the transmission of a force along a bone or set of bones made rigid by ligamentary attachments or muscular contraction in such manner that it is resolved into forces acting in two or more directions, one of which crosses the long axis of the bone and acts as if it had been applied directly at the point of least resistance in a lateral or transverse direction. The effect is modified greatly by the anatomical structure and form of the bone, the attitude of the limb, the contraction of the muscles, and the direction of the blow. Thus, a fall upon the hand may break the lower end of the radius, both bones of the forearm, the humerus, or the clavicle; a fall upon the foot may fracture the calcaneum by direct violence, or the bones of the leg, the thigh, or even the vertebral column or skull by indirect violence. Pressure against the sternum may break the ribs by exaggerating their curves; pressure against the wings of the pelvis may produce a similar result.

The best example of the fracture of short bones by indirect violence is furnished by the spinal column, the bones of which, considered as a group, constitute a long bone with several curves, resembling the clavicle in its entirety and in the mechanism of its fractures so far as they are produced by exaggeration of a normal curve.

Indirect fracture by traction upon a bone occurs exclusively at apophyses which give attachment to strong ligaments through which the force is conveyed. Thus, the internal malleolus is torn off by the forcible rotation outward (eversion) of the sole of the foot; the internal lateral ligament is put upon the stretch, and if, as is usually the case, its attachment to the bone is stronger than the cohesion between the particles of the bone itself the latter yields and a transverse fracture results. A similar mechanism is sometimes found at the elbow on the inner, and possibly also on the outer, side.

b. Fractures by muscular action. Under this head are included only those fractures in which the rupturing force is exerted by the muscles alone without the aid of any external violence. It is of course evident that if an individual breaks his skull or a limb by running or striking against a solid object the force that causes the fracture is developed by the action of his muscles, but the mechanism is the same as if he had fallen from a height or as if his body was at rest and the object with which he has come into contact was in motion. Only those cases are considered to be fractures by muscular action in which the action is exerted directly by the muscles upon the bones to which they are attached (mediately or immediately), either as direct traction, or in fracture of the patella or of the olecranon, or obliquely, according to the principle

of the lever, or by exaggerating the normal curve of the bone by drawing upon one of its extremities. Mention has already been made (page 74) of the influence exerted by the contraction of the muscles in favoring the production of fracture by external violence, an influence which is demonstrated experimentally by the extreme difficulty of producing the common indirect fractures in a cadaver by throwing it from a height, and which is explained in part by the fact that the muscles when rigid hold contiguous bones together so closely and so firmly that they practically form one long bone more or less curved and therefore more exposed to fracture by over-bending, and in part by the additional strain which the muscles exert upon the bones.

Some authors have expressed the opinion that no bone can be broken by simple muscular contraction unless it has previously undergone some change that has diminished its strength, but this opinion must be looked upon as an attempt to explain away by an unfounded, or at least unproven, assumption a difficulty which does not really exist. It is unquestionable that in all cases of fracture by slight muscular action a previous change in the strength of the bone must have taken place, and in many of them this change has been demonstrated by direct examination. Several such cases have been described under the different predisposing causes of fracture. But it is no more logical to claim that such a change has preceded every fracture by muscular action than it would be to make the same claim for fractures by external violence; it can rest only upon the assumption that the power of resistance of a normal bone is superior to any force that a muscle or group of muscles can exert upon it under the most extreme and unusual circumstances, whereas, on the contrary, nature's precautions and adaptations are as a rule calculated upon the basis of the probable, not of the exceptional. Such a position may be taken with propriety with reference to all fractures produced by slight causes in the old, the weak, or the cachectic, or in those who have suffered pain at the point of fracture for some time previous to the accident, but it is entirely unsupported by proof in the rarer, but still sufficiently numerous, cases of fracture of the shaft of a long bone produced by a violent effort in a healthy athletic man, and in the common ones of fracture of the patella or olecranon.

The effect of muscular action is manifested in all the degrees of varying importance between its relatively unimportant additions to the effects of external violence, and those cases in which it is the sole agent of the fracture of a healthy bone. The intermediate degrees are presented by those fractures, usually of weakened bones, in which moderate muscular action has acted either alone or combined with some external violence. In the first case, when the power of the muscle is exerted in the same direction as the external violence, it increases the fracturing force by just so much: and, by prolonging its effect after the fracture has been made, it also increases the displacement of the fragments and the laceration of the soft parts. The principal interest of the intermediate cases is connected with the cause of the exceptional fragility of the bone, and as it has been previously discussed, with illustrative examples, in that connection, it does not require further attention here.

The commonest examples of fracture by muscular action alone are

furnished by the patella and the olecranon, and similar, but rarer, examples have also been given by other apophyses to which powerful muscles are attached, such as the posterior portion of the calcaneum, the coronoid process of the ulna, and the coracoid process of the scapula. These fractures are almost exactly transverse, and in most cases show that the resistance of the bone to direct traction is less than that of the tendons through which the traction is exerted. The patella is a sesamoid bone developed within a tendon, and is practically the weakest point in it, for the great majority of the cases of its fracture are, apparently, fractures by direct muscular action unaided by any leverage; the bone is broken as a rope is, by direct traction upon it.

Of the long bones the humerus is the one most frequently broken in this manner; out of 85 cases of fracture of the limbs by muscular action collected by Gurlt[1] 57 were fractures of the humerus, 15 of the thigh, 8 of the leg, and 5 of the forearm. He gives also some remarkable cases of fracture of the sternum and of the vertebral column by unaided muscular action. The mechanism seems in most cases to be the same as in indirect fracture; in some the fracture takes place at the point of insertion of the muscle, and in others the elements are too complex and too uncertain to be explained theoretically. In a comparatively small number of cases the fracture was caused by the convulsions of epilepsy or tetanus, and in others by reflex contractions or spasms in limbs that had been long paralyzed, but usually the cause was a violent voluntary muscular effort to avoid a fall, or to throw a stone, or lift a heavy object. The following cases taken from Gurlt illustrate the different fractures and the different methods in which they may be produced. It must be remembered that fractures produced during convulsions need to be closely examined in order not to overlook the possible addition of external violence by a fall from the bed or by striking the limb against a solid object.

In a negro boy, twelve to thirteen years of age, affected with tetanus, both thigh bones were broken "at the neck," probably just below the trochanter, by the contraction of the muscles, and the fragments forced through the skin on the outer side of the limb. An inch had to be removed from one of the bones before reduction could be effected. Recovery with angular displacement followed.

Lente[2] reported a case of fracture of both femurs at an interval of eight months in a child twelve years old, during epileptic fits. The fractures were at the junction of the upper and middle thirds of the bone; the first united with considerable shortening; the patient died six weeks after the occurrence of the second fracture, which had not united.

The majority of the recorded fractures of the humerus were produced by the effort of throwing some object, a ball or a stone, with violence, and Gurlt thinks the mechanism is the same as that by which a stick is broken when it is grasped at one end and snapped sharply like a whip. The contraction of the deltoid arrests the bone suddenly and the impetus of the lower end of the humerus causes the break, which, however, may take place at either end or at the middle of the bone.

[1] Loc. cit., vol. i. p. 232.
[2] Am. Med. Times and Advertiser, July 21, 1860, quoted by Hamilton.

An athletic man,[1] thirty-four years old, accustomed to lift heavy weights, broke his humerus with an audible snap just below the insertion of the deltoid by the effort made, on a wager, to throw a stone weighing about two ounces the distance of a hundred yards. Recovery in six weeks.

An apparently robust and healthy man,[2] twenty-one years old, broke his humerus in the lower third by throwing an oyster shell with some force out upon the ice from the bank of the river. Recovery in the usual time.

A powerful and healthy student[3] broke his humerus in two places in a duel while making the stroke known as "Quarte."

Gurlt gives also eleven cases in which the humerus was broken during that trial of strength in which two men place their elbows upon a table, clasp hands with the forearms parallel and vertical, and strive to force each other's hand backwards. In almost all these cases consolidation took place within the usual limits of time.

Fractures of the femur are rarer than those of the humerus. They may occur at any point on the shaft, and in the recorded cases have been the result of an attempt to kick, to avoid a fall, or to rise from the ground without aid, or of cramps, excited in one case by drawing on a tight boot, and in another by turning in bed.

A colonel of cavalry,[4] 36–38 years old, of middle size and great muscular power, broke his thigh at the junction of the upper and middle thirds by kicking at and missing his servant.

Barnard Van Oven,[5] described before the Royal Medical and Chirurgical Society, a fracture of the thigh sustained by himself. He was 56 years old, healthy and strong, and free from taint of cancer, scrofula, syphilis, etc. He was awakened one night by a sharp, cramp-like pain above the knee, and as he felt the part with his hand and noticed that the muscle was tense, he heard a snap, followed by relaxation of the muscle, crepitation, and diminution of the pain. Examination showed a transverse fracture of the femur three inches above the knee; complete recovery in four months.

A cavalry man,[6] 29 years old, while trying to rise from a sitting position on the ground without the aid of his hands, broke his right thigh transversely at its middle. A diseased condition of the bone could not be shown.

Hamilton[7] reports a fracture of the shaft of the femur in a large and perfectly healthy man, occasioned by a twist of the leg in rolling ten-pins, and Gurlt mentions an unrecorded case of fracture of the thigh at two points, produced by a similar cause, in a not entirely healthy man of 35 years.

Gurlt's eight cases of fracture of the leg comprise four of both bones,

[1] Guthrie, Lond. Med. and Surg. Journal, 1835, vol. vi. p. 478.
[2] Kirkbride, Am. Journal Med. Sciences, 1835, vol. xvi. p. 33.
[3] Keil, De Fragilitate Ossium, etc. Vratislav, 1845, p. 23.
[4] Journal universel des Sciences Méd., t. xi. p. 373.
[5] Lancet, 1852, vol. ii. p. 591.
[6] Gaz. Méd. de Paris, 1842, p. 218.
[7] Fractures and Dislocations, 3d ed. p. 30.

one of the tibia, and three of the fibula alone, the latter being fractures at the upper end of the bone by the vigorous contraction of the biceps.

A small rather corpulent woman, 45 years old, slipped on the left foot while descending some steps, made a violent effort with the right leg to avoid a fall, felt at once a very severe pain in the latter, and fell in a sitting posture upon the bottom step. An immediate examination showed a fracture of both bones at the middle of the leg, the muscles of the calf strongly contracted, and a small wound of the skin over the anterior angle formed by the fragments.

A woman,[1] 52 years old, mistook in the dark a door leading into the cellar for one opening into a closet, and, recognizing the mistake as she put her right foot forward, drew herself instinctively backward, and felt at the same moment something snap in her left leg, upon which the weight of her body rested. She fell and rolled down the steps. On examination, a fracture of the left fibula just below its head was found.

Fracture of either or both bones of the forearm has been caused by the wringing of wet clothes, or by shovelling. The accident is among the rarest of fractures by muscular action, only five cases being reported by Gurlt.

A healthy girl,[2] 18 years old, while wringing clothes, felt a sudden, sharp pain on the inner side of the forearm above the wrist. Three days afterwards a fracture of the ulna 67 millimetres ($2\frac{1}{2}$ inches) above the wrist was recognized by the abnormal mobility and crepitation. Union in a month. A year previously she had dislocated the lower end of the ulna backwards, which must have interfered with the movement of supination.

A woman,[3] 30 years old, broke the radius in its lower third with severe pain, while wringing two heavy towels. Recovery in 36 days.

A healthy, powerful lunatic,[4] while using a shovel heard two distinct snaps in his right forearm, and found himself unable to use the limb. The next day Malgaigne found a fracture of the radius near its centre, and a fracture of the ulna about an inch nearer the wrist, with considerable displacement.

Fractures of the clavicle have been caused by the effort of raising a heavy object, shovelling, and striking backwards, or with a whip.

Malgaigne[5] reports two cases of fracture of the clavicle caused by an effort to toss a heavy body upwards; one in the outer half of the bone in a man 41 years old; the other in the inner third in a youth of 18 years.

Gosselin[6] reports a case of fracture of the clavicle in its middle third, caused by the effort to raise a heavy piece of marble and place it upon the shoulder of a fellow workman.

Fractures of one or more ribs are not infrequently caused by violent coughing. The sternum has been broken in four recorded cases by the violent straining and bending backwards of the body during the expulsive efforts of parturition, and there are three or four cases of fracture

[1] Revue Méd. Chirurg. de Paris, t. xvi. 1854.
[2] Labatt, Dublin Med. Press, 1840, and Gaz. Médicale, Paris, 1840, p. 475.
[3] Gazette des Hôpitaux, 1844, p. 224.
[4] Malgaigne, Fractures and Luxations, vol. i. p. 585.
[5] Loc. cit., p. 464.
[6] Clinique Chirurgicale, 1873, vol. i. p. 413.

of the vertebral column by muscular action alone,[1] and four of the scapula.

Monteggia[2] saw a man 50 years old who had broken a rib by violent coughing. The crack was heard by members of the family present in the room. No further details.

Hilton[3] reports the case of a man who broke a rib by muscular action while trying to mount a spirited horse. He was treated for a long time for pleurisy before the fracture was recognized.

A primipara,[4] 24 years old, taken in labor sought to hasten delivery by forcible voluntary expulsive efforts, bending backwards and resting on her elbows and heels. During this effort she felt a sudden sharp pain and a snap in the middle of the breast, and said at once that something had broken there. No attention was paid to the statement until five days afterwards when, peritonitis having appeared, an examination was made and a painful swelling found in the upper portion of the sternum, with quick and difficult respiration and increased pulsation in the large vessels. The patient died on the 17th day, and at the autopsy a transverse fracture of the sternum was found $1\frac{1}{2}$ lines above the junction of the body and the manubrium. The edges of the fracture were separated, and an inflammatory exudation as large as a hen's egg and containing pus was found in the anterior mediastinum.

A soldier[5] bathing in the Sambre dived into the river, and, not reappearing, was sought for and brought out. His body showed no trace of external violence, but there was paralysis of all the limbs, loss of sensation, inability to hold up the head, pain at the posterior and lower part of the neck, priapism, frequent desire to urinate. He said that as he dived he saw the water was too shallow, and in the effort to avoid striking against the bottom he jerked his head violently backward and at once lost consciousness. He died the same night, and the autopsy showed a transverse fracture of the body of the 5th cervical vertebra a little below its centre; the cord and dura mater were intact, but there was an extensive extravasation of blood between the latter and the bone and also on the outside of the column.

A servant[6] engaged in preparing a lamp raised his arm quickly to arrest the action of an escaping spring and felt something give way in it. The arm fell powerless by his side, and the greater portion of the acromion was found to have been broken off; crepitation very distinct. Recovery in six weeks.

C. Intra-uterine Fractures and Fractures during Delivery.

Fracture of the limb of a child during its delivery through the natural passages of the mother is of rather frequent occurrence and is usually the result of manual or instrumental interference to correct a faulty presentation or to supplement the insufficient expulsive power of the uterus. Such fractures belong to the class of fractures by external violence and

[1] See Fractures of the Vertebræ, chap. xiii.
[2] Archives Générales, 1838.
[3] Lancet, 1852, vol. i. p. 143.
[4] Chaussier, Revue Méd. franç et étrang, t. iv. 1827, p. 264.
[5] Réveillon, Arch. Gén. de Méd., 1827, t. xiii. p. 449.
[6] Wildbore, Lond. Med. Gaz., New Series, 1846, vol. iii. p. 708.

present no features of especial interest; but there are others in which the fracture is caused by the expulsive efforts of the mother alone. An arm or leg is engaged between the body of the child and the rigid parts of the mother and the humerus or femur broken, sometimes with an audible snap, as the child is forced through the passage. Thus, in one case during the spontaneous delivery of the shoulders, the arm, which lay across the child's breast, was heard to snap and a fracture was found at its upper third; in another, a breach presentation with very forcible pains, the femur was broken by pressure against the symphysis pubis; and in a third, where the head and left hand presented simultaneously and were violently forced through the pelvic outlet, a fracture of the left humerus was found.

Fractures within the uterus have been caused in a few cases by a bullet or sharp instrument that has at the same time perforated the abdominal wall of the mother; the interest attaching to them, however, is statistical rather than practical, for in the three cases collected by Gurlt miscarriage followed, with death of the fœtus in every case, and of the mother in one.

The possibility of the occurrence of fracture within the uterus as the result of external violence without perforation of the abdomen of the mother, or, in some cases, of unknown causes, has been proved by the delivery of children presenting fractures of different bones in various stages of repair. It is not always easy to say, when a child is born with a fracture, whether it was caused during the delivery or at an earlier period, or whether it was due to external violence or to the contractions of the uterus. And furthermore, it is not always possible to say whether the apparent fracture is actually one or only a malformation, a defect of ossification or development, or a separation of the epiphysis in consequence of a syphilitic or inflammatory process. Gurlt collected eight cases in which the causal relation between an injury received by the mother during pregnancy and the fracture observed in the child seemed to him to be clearly demonstrated, and twenty-five others in which more or less doubt existed as to the cause of the fracture or the character of the lesion. The injury in the first eight cases was either a fall from a height or a direct and violent blow upon the abdomen; and the bones broken were those of the thigh, leg, arm, and forearm, and the collar bone. The autopsy in three cases showed union of the fracture with undoubted callus and more or less overriding of the fragments; in three others the fracture had led to suppuration and perforation of the skin, and in two there was a large callus (humerus and clavicle).

The remaining cases include some in which an undoubted fracture existed, but with no history of external violence, and some in which the coexistence of malformations threw some doubt upon the character of the supposed fracture, and others in which the fractures were so numerous and so symmetrical that they must have depended upon some general cause acting probably upon the epiphyseal cartilages. It has recently been shown by Parrot, as the result of his researches concerning the lesions of syphilis in infancy, that this disease has a marked tendency in the fœtus and infant to affect the tissues by which the growth of the

bone is carried on, and to weaken the connection between the shaft and the epiphyses.

A woman gave birth prematurely to twins, one of which presented an old fracture of the femur. The bone projected more than an inch through the skin and was carious. About six weeks before delivery the mother, while making some slight exertion, heard something snap in her abdomen, and felt thereafter, on every movement, a pricking as by the point of a knife.

Blasius[1] reported the case of a healthy, well-formed child with an obtuse angular deformity at the junction of the lower and middle thirds of one leg; the skin presented a cicatricial-like retraction at the angle, where it was also unusually adherent to the bone. The ankle was free, the heel drawn up, and the inner border of the foot directed upwards. The limb was smaller than the other, and had only two toes and two metatarsal bones in the foot. There was a doubtful history of a blow received upon the abdomen during pregnancy.

Chaussier saw in 1813 a child that died twenty-four hours after delivery, whose skeleton presented 113 solutions of continuity, 70 of which were in the ribs; a considerable number had become consolidated.

Hedland saw in the child of a woman who had had a violent fall during pregnancy both femurs broken near the neck, both tibias and fibulas just below the knee, and both arms near the elbow. The lesions on the two sides corresponded closely in position. At each fracture there was some pinkish pus, and the ends of the bones were roughened. Probably, as Gurlt suggests, this was a separation of the epiphyses due to an inflammatory process of unknown origin.

Gurlt[2] gives the following as the only one of the cases of so-called *self-amputation* in which there is any probability that the loss of the member was due to a fracture accompanied by laceration of the soft parts or compression of the main artery sufficient to cause gangrene.

A pregnant woman thirty-three years old fell from the top of a ladder, and lay unconscious upon the ground for some time. During the following days blood, and afterwards bloody water, escaped from the vagina, but she suffered no abdominal pain and continued to feel well. Delivery took place in due time, eight weeks after the accident. All the left upper extremity of the child below the middle of the arm was lacking, and the end of the remaining portion of the humerus projected slightly through a reddish-brown, moist, but not bleeding or suppurating wound which formed the surface of the stump and which cicatrized promptly. The amputated portion of the limb came away with the afterbirth; it was composed of the hand, forearm, and lower portion of the arm; its skin was shrunken, the nails complete, extensive extravasation of blood in the subcutaneous tissue, and the end of the humerus, which presented a toothed surface of fracture, projected about one-fourth of an inch.

[1] Monatschrift für Geburtsk. und Frauenkrankheiten, Bd. xii. 1858, p. 129, quoted by Gurlt.

[2] Loc. cit., vol. i. p. 122.

CHAPTER V.

SYMPTOMS AND DIAGNOSIS.

The symptoms produced by a fracture, the facts upon the existence or absence of which the surgeon relies in making a diagnosis, are divided in accordance with the common semiological practice into two groups, the *objective* and the *subjective* or *rational*. The symptoms included in the former are those which can be directly observed by the surgeon; in the latter they are those for his knowledge of which he has to depend more or less completely upon the statements of the patient. The former are the most important and are the only ones which have a valid claim to be considered pathognomonic; they include, 1st. *deformity* of the limb or part, 2d. *abnormal mobility* at the point of fracture, 3d. *crepitation*. The second group includes, 1st. *pain*, 2d. *disturbance of function* or *loss of power*, 3d. *history* of the case and of the patient.

Except in those comparatively infrequent cases, where the injury or the deformity of the limb is of such a character that the diagnosis is not for an instant in doubt, the symptoms of a fracture are not so prominent that a careful examination can be dispensed with, and in some cases they are so obscure that even the most experienced and skilful surgeon may remain in doubt. An examination should always be conducted systematically and thoroughly, and the appearances presented by the injured limb should always be compared with those of its uninjured fellow, both for the easier detection of slight changes and to avoid the mistake of thinking some chance congenital variation to be a result of the injury. If the pain is so great as to prevent the necessary explorations, an anæsthetic, preferably ether, should be used, especially if the suspected fracture is in the vicinity of a joint; and if the swelling of the soft parts masks the bones and interferes with the examination, the decision should be postponed for a few days until the swelling shall have been reduced by poultices or cooling lotions. In doubtful cases the question should always be asked whether the affected limb or its fellow has suffered any previous injury that might have altered its form, for otherwise a sprain or a contusion in the neighborhood of a deformity remaining after the healing of an old fracture might be mistaken for a recent fracture, or the limb which is used for the purpose of comparison may itself have been shortened or otherwise deformed by a previous injury.

Objective Signs.

Deformity.—This term is here employed in its widest sense to include changes in the relations of the fragments of the bones to each other and

the modifications in the appearance of the limb or part of the body produced by those changes, by the effusion of blood, and by the later inflammatory processes. In other words, it includes changes in the length and diameter of a limb, in the form and color of a surface, in the resistance of the tissues to pressure, and in the relations of certain bony points or prominences to each other.

The changes in the relations of the fragments to each other and the resultant modifications of the form of a limb, have been described in detail under the head of *Displacements* (Chap. III.). Many of them are so marked that they are recognizable by simple inspection of the part, while others are brought to light only by careful measurements and comparison with the opposite limb. These measurements are used in practice only to recognize longitudinal and lateral displacements and those by which a limb is shortened or the diameters of an articular extremity modified. As a rule, to which there are few exceptions, mensuration, to be of value, requires that the injury should be confined to one limb, to one side of the body, in order that the other may serve as a standard of comparison by which the change in the first may be recognized. The reason of this is the absence of fixed proportions between the different parts of the skeleton, such as would enable us to calculate in any given case from the height of an individual, for example, the length of a bone or the distance between any two points. Among the possible exceptions to this rule are the relations of the great trochanter of the femur to a line drawn from the tuberosity of the ischium to the anterior superior spine of the ilium, and those of the styloid process of the radius to the lower extremity of the ulna, both of which may be used with considerable accuracy in cases of fracture of the neck of the femur or lower extremity of the radius even when the opposite limb has been rendered unsuitable for the purposes of comparison by disease or injury.

The chief difficulty in employing mensuration is that of finding fixed and well-defined points upon the body between which the desired measurements can be made. The ones employed in fractures are bony prominences or edges sufficiently near the surface to be readily recognized and felt, but as they are all more or less rounded, absolute accuracy in measuring the distance is impossible.

Another cause of error or of uncertainty lies in the differences which have been found to exist often in the limbs of the same individual, and which sometimes are very considerable. The occasional existence of such a difference not having a traumatic or pathological origin appears to have been known for some time. Duparque[1] published a paper in 1863 in which he called attention to the influence of certain professions in diminishing the growth of one arm, as compared with the other, and to the importance of the recognition of this fact in the diagnosis and treatment of fractures. Although he refers to it as a fact generally known to the profession, I do not find it mentioned in the general treatises on surgery or the special ones on fractures; and, in this country at least, attention was first called to this natural asymmetry in the length of

[1] Gaz. Hebdomadaire, 1863, p. 55.

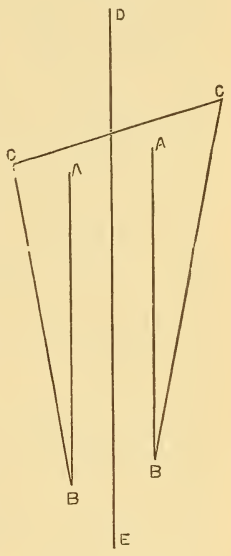
the lower limbs in a paper published in the American Journal of the Medical Sciences, April, 1873, by Dr. Wm. C. Cox, and inspired by Prof. Thomas G. Morton, of Philadelphia, and subsequently, February, 1877, but independently, by Dr. Wight, of Brooklyn. The statements then made have been since confirmed by many observers, and the existence and diagnostic importance of a normal asymmetry are now generally recognized. Prof. Morton[1] examined 513 boys, from eight to eighteen years of age, and found inequality of the lower limbs in 272, varying from $\frac{1}{8}$ inch in 91 cases, and $\frac{1}{4}$ inch in 100, to $1\frac{1}{8}$ inch in 2 cases, and $1\frac{3}{8}$ inch in 1 case. In a personal adult case, verified by dissection (one of a series of 16 cases examined in the dissection room in 1877), the distance from the anterior superior spine of the ilium to the tip of the external malleolus was half an inch greater on the right side than on the left, and the bones showed no trace of injury; and in a case now under my observation at Bellevue Hospital the left humerus is half an inch longer than the right. It is evident, therefore, that small differences, say up to half an inch, must be accepted with much reserve in making a diagnosis, or in estimating the result after repair.

Other difficulties and causes of error in measuring are found in the swelling of the soft parts of the injured limb, which may prevent the measuring-tape from being drawn straight, and in the varying angles between the axis of the limb and the line of measurement. The first is not likely to be great, and is still less likely to be overlooked; but the latter is a frequent source of error. It is rare that the two fixed points between which the measurement is made are both upon the limb, or the bone, whose length is in question; one of them is usually upon the trunk, and lies at a certain distance from the centre of motion of the limb. Consequently any change in the position of the limb changes the actual distance between the two fixed points that have been chosen. For example, in measuring the length of the lower extremity the points taken are the anterior superior spine of the ilium and the tip of the external malleolus; the former lies several inches above and to the outer side of the centre of motion of the coxo-femoral joint, and therefore when the limb is in abduction the distance between the two fixed points is less than when the limb is parallel to the long axis of the body. If a comparison is to be made between the two limbs, it is essential that their positions with reference to the pelvis should be the same, and therefore care must be taken that the ankles are equidistant from a line drawn at right angles to another connecting the two anterior superior spines. It is not sufficient that the limbs should be parallel to the long axis of the body, for the pelvis may be inclined to it, and a glance at fig. 57 will show the result of such an inclination, one limb being virtually abducted and the other adducted, so that while the lines A B and A B, which represent the actual length of the two limbs, are equal, the lines C B and C B, which are the ones measured by the surgeon, are unequal. If only one upper fixed point in the median line, as the umbilicus or the sternum, is used for both measurements the effect of an inclination of the pelvis would be still greater.

[1] Surgery in the Pennsylvania Hospital, 1880, p. 287.

Similar difficulties and uncertainties exist in transverse and peripheral measurements of the limbs to an even greater degree. The swelling of the soft parts not only increases the bulk of the part, but it also obscures the bony prominences, and places them at a greater distance below the surface, so that an accurate measurement of the distance between points upon the opposite sides of a bone is practically impossible. Malgaigne recommends the use of needles or pins passed through the soft parts until they touch the bone as a means of measuring the thickness of the overlying tissues. By subtracting the sum of these measurements from the diameter of the limb at that point the breadth of the bone is obtained. Theoretically the method is correct, but the practical difficulties are great, for the very swelling which renders the method necessary obscures the land-marks, and makes it impossible to insert the needles with accuracy at the desired points. For this and for angular and rotatory displacements the trained eye of the surgeon, aided by careful and minute consideration or palpation of the anatomical land-marks and comparison with the other limb, is the best guide, and will often recognize the change at the first glance.

Fig. 57.



The appearance of the limb may be still further modified by an abundant extravasation of blood poured out from the vessels of the bone and the adjacent parts, and either collected in a mass or infiltrated among the tissues. Except when the bone is subcutaneous, this extravasation is not at first accompanied by discoloration of the surface, and is then to be recognized only by the greater size and firmness of the limb, or possibly by the peculiar crackling of the coagulated blood felt when the part is handled, a crackling which has been compared to that of dry starch, or of snow compressed in the hand. The swelling may be so distinctly limited, and rendered so firm by coagulation or the tenseness of the tissues that cover it, as to give to the exploring hand the sensation of a solid substance, and thus be mistaken for the displaced end of the broken bone. Malgaigne has reported a case in which he mistook such a collection of blood for the projecting end of a broken femur. In case of doubt the diagnosis could be made by the aid of acupuncture needles, the introduction of which through the skin would show the consistency of the mass, and prevent a collection of blood from being mistaken for bone. A similar diagnostic use of needles has been suggested when doubt exists as to the presence of a fissure, or as to the identity or connections of some portion of bone, or bony prominence, that can be felt through the skin, but it is doubtful if much can be gained by this method of exploration. It is, of course, possible that the point of a needle might slip into a fissure or pass between two fragments in such a manner that it might be alternately pinched and freed by bending the limb, but it is improbable that the occasion would often arise when the value of the

information to be gained would justify even the slight inconveniences of the exploration, except in the contingency first mentioned, that of doubt as to the character of an abnormal mass, and in the search for mobility of the fragments in the case of a suspected fracture involving a joint.

Ecchymosis is a symptom that is rarely absent, although its appearance may be delayed for several days. Blood is freely poured out from the medullary canal and the spongy tissue of a bone, and in cases of fracture by indirect violence it may make its way along the muscular planes and first appear under the surface at a considerable distance from the seat of injury. Under such circumstances, its tardy appearance at a distance from a painful point upon the course of a bone, with the history of an injury, it raises a strong presumption of fracture, although it is by no means pathognomonic. In fractures by direct violence the ecchymosis appears promptly and at the point where the injury was received, and is often due as much to the contusion of the soft parts as to the fracture.

The coexistence of an external wound is not to be lightly taken as a proof that the fracture is compound. The blow which has caused it may also have produced an indirect fracture at a considerable distance, or, even if the position of the fracture corresponds to that of the wound, the deeper soft parts may still remain undivided and prevent communication between the two. In cases where the bone does not protrude and cannot be felt by cautious exploration through the wound, the diagnosis of a probable communication may be made if the hemorrhage is profuse, prolonged, and venous in character, and if it contains scattered oil-globules within the first twelve hours.

In fractures communicating with joints a very notable and characteristic deformity is caused by the filling of the cavity of the joint with extravasated blood or an inflammatory effusion, the character and situation of which are shown by its limitation within the boundaries of the articular capsule.

Abnormal Mobility.—Mobility appearing after injury at a point in a bone where it did not previously exist, and permitting the bone to be lengthened, shortened, or bent at an angle, or allowing a portion of it to be moved while the other portion remains at rest, is pathognomonic of a fracture, but unfortunately it is not always present or recognizable. In an impacted fracture the two fragments may be so firmly wedged together that mobility does not exist; and in a partial or a toothed fracture, or in fracture of one of two bones, as in the forearm or leg, it may be so slight as not to be recognizable; and in a fracture of a short bone, or in one near the articular end of a long bone, one or both fragments may be too small to be grasped with sufficient firmness for this exploration. In fracture of the ribs, or sternum, or fibula, the natural elasticity or mobility of the bone may deceive if not taken into consideration, or raise a doubt if it is.

The manipulations employed for the detection of abnormal mobility vary with the seat of fracture and the kind of mobility which is sought to be produced. In fracture of the shaft of a long bone the surgeon seeks first to produce an angular displacement by passing his hand under the limb at the supposed seat of fracture and gently raising it, or by grasping the two extremities of the bone firmly and moving the lower

one slightly from side to side while the upper one is held stationary. Or he may grasp the limb with both hands close to the fracture, and produce transverse displacement by moving the fragments bodily in opposite directions. In fracture of the shaft of the fibula a method recommended by Dupuytren is to place the fingers of both hands over the inner aspect of the limb and the thumbs against the fibula, one above, the other below, the suspected fracture; then by making pressure alternately with the thumbs the independent movement of either fragment may be detected. A similar manipulation can be used upon the radius or ulna.

In fracture of the upper portion of the femur in a stout person, or of the neck of the humerus, or of the upper end of the tibia where a lateral or angular displacement cannot be recognized, recourse must be had to slight rotation of the lower portion of the limb, while the upper portion is so held that its bony prominences can be distinctly felt by the fingers. Abnormal mobility is recognized by the failure of the manipulation to transmit the rotatory movements to the upper fragment. The test is a delicate one, and it is essential that the communicated movements should be slight, for otherwise the attachments of the soft parts or the interlocking of the fragments may prevent the success of the manœuvre which, moreover, for obvious reasons must fail in partial and impacted fractures.

In intra-articular fracture of the lower end of the humerus or femur, or in fracture of an apophysis, the surgeon's aim must be to grasp each fragment as firmly as possible, and to move one upon the other in the direction of the line of fracture.

In exceptional cases it is possible to give a fragment a tipping or see-saw motion; thus, by pressing the tip of the external malleolus inward, when the fibula has been broken just above the ankle, the upper end of the lower fragment may sometimes be felt to move outward, and when the internal malleolus has been broken transversely a similar rocking movement can be given to the fragment by pressure upon its anterior and posterior edges. In this manœuvre the sliding of the skin is very liable to be mistaken for movement of the bone, especially if the part is swollen and tense, and should be guarded against as far as possible by pressing the fingers towards each other so as to relax the skin between them.

All these manipulations should be made cautiously, gently, and with close attention, and arrested as soon as the desired information is obtained, in order that the patient may not be exposed to unnecessary harm by rupture of remaining adhesions or by additional laceration of the soft parts.

Crepitation.—This is the sound produced, or the sensation communicated to the hand of the surgeon, by the friction of broken fragments of bone against each other. It is as pathognomonic of fracture as is abnormal mobility, and these two symptoms usually coexist, for crepitation cannot be produced except by the movement of the fragments, and when the latter is sufficiently marked to be recognizable crepitation is rarely absent.

Crepitation has been compared, for the instruction of those who have never felt it, to the friction or contact of various bodies, such as nuts in a bag, or gravel; but these comparisons can do nothing more than con-

vey the most general idea of the sensation, one that is little, if at all, more definite than that which an ordinary imagination would evolve from the known conditions. The simplest means of acquiring a conception of crepitation in default of actual practice is to break a bone or the limb of a dead animal and rub the fragments together with different degrees of force. The sensation is not the same in all cases, it runs through all the grades between the sharp click of two hard points or edges and the dull, muffled contact felt when one of the pieces, probably, is covered with periosteum, or the crackling and grating of comminuted fragments and broad surfaces. Some of its forms are practically identical with the friction sounds obtained by the movement of joints whose surfaces are altered by disease, and although it is usual to speak of a recognizable difference in the quality of these sensations, the one being called *hard* or *rough*, the other *soft* or *smooth*, the diagnosis in case of doubt must depend upon circumstances other than this difference.

Crepitation is perceived rather through the hand than the ear, although in some cases there is a distinct sound audible to bystanders who are not in contact with the patient. It is to be sought by the same methods as abnormal mobility, and also in the ribs or flat bones by placing the palm of the hand over the supposed seat of fracture and pressing gently in different directions, or in the expectation that movements sufficient to produce the symptom will be communicated to the fragments by the respiratory efforts of the patient. Direct auscultation, with or without the stethoscope, is sometimes employed, but it is inferior in accuracy to the hand when the parts can be well grasped. It is useful in fracture of the ribs or sternum. Patients can usually feel the click or grating when the limb is handled.

Crepitation cannot always be produced when there is a fracture. It is essential to its production that there should be at least two fragments movable at will one upon the other, and therefore its presence is conditioned, not only upon the same circumstances as that of abnormal mobility, but also upon the contact, and, in a measure, the character of the broken surfaces. If the fragments are completely separated by longitudinal or transverse displacement, and are not brought into contact by traction or pressure, if a piece of muscle or periosteum is engaged between them, or if sufficient time has elapsed to allow them to become covered with granulations, their movements will not cause crepitation, and it is a matter of daily experience that the same manipulation which produces crepitation at one moment may fail to produce it at the next. The reasons therefor can sometimes be observed directly in compound fractures of subcutaneous bones, such as the tibia, where the movements of the patient or the involuntary contractions of the muscles of the limb will be seen through the wound to change the relations of the broken fragments.

The same reasons which make it undesirable to attempt a verbal description of the sensation of crepitation apply equally to the more or less similar sensations produced by other conditions with which the crepitation of fracture may be confounded. The best guard against error is found in a knowledge of the errors to be avoided and in a careful study of the case with those errors borne in mind. Those other conditions are:

roughening of the articular surfaces of neighboring joints, which produces "friction sounds" when they are moved; inflammation of the sheaths of tendons or of bursæ, giving rise to a fine crackling when they are handled; emphysema due either to the escape of air into the tissues from a wounded lung or to decomposition with the production of gas; the crackling of coagulated blood, and a pleuritic friction sound when heard after an injury to the wall of the thorax.

Subjective or Rational Signs.

Diminution, or *total loss*, *of the functions* of the limb or part involved is a common result of fracture, but as it may also be occasioned by a simple contusion it is not pathognomonic of the former lesion. The immediate causes of this loss of power are various: it may be due to the breaking of the bone between the points of attachment of the muscles which control it and the fixed point about which its normal movements take place; or it may be due to pain excited by the slightest motion of the fragments or by the contraction of the bruised muscles, or to the paralyzing effect of the dread of pain upon the will of the patient. An extreme instance of the latter was recently furnished in a patient who came under my care for fracture of the olecranon, and in whom communicated movements of pronation and supination were absolutely prevented by muscular rigidity during the first twenty-four hours, although made with entire freedom afterwards. The loss of function may be complete, as after fracture of the shaft of the femur or of the humerus, or it may be so slight as to be overlooked; and the former is no more a proof of the severity of the injury than the latter is of its unimportance, for while on the one hand a severe contusion, or even the mere thought of having received a fracture, may prevent voluntary movements of a limb, on the other, patients may walk a considerable distance or raise the leg in bed after having broken the neck of the femur or the tibia. In a personal case, a man 66 years old, broke the neck of the femur by a fall down a flight of stairs, he rose without assistance and walked down another flight before he lost control of the limb. The fracture was found at the autopsy to be a smooth, non-impacted, transverse fracture at the junction of the head and neck of the bone. Many similar cases are on record, and Stanley[1] has recorded a still more remarkable case of a man who walked four miles with the help only of a cane after his tibia and fibula had been broken by the kick of a horse.

Other modifying circumstances are found in delirium, which, by rendering the patient indifferent to pain, allows him to move the broken limb, and in injury of a joint by dislocation or sprain which compels immobility.

Pain, either spontaneous, or on pressure, or on movement of the limb, is a constant acompaniment of fracture, and under some circumstances is a valuable aid to diagnosis, especially when the fracture has been caused by indirect violence or by muscular action. In suspected fractures by direct violence, its diagnostic value is less because the pain

[1] London Med. Gazette, 1844, vol. i. p. 273. Quoted by Gurlt.

may be due to injury of the soft parts, especially the periosteum, occasioned by the blow. It should be sought for by gentle pressure with the finger along the course of the bone, and if it is found on repeated examination always at the same point, and if the area within which it is found or is most severe is small or is distinctly circumscribed, I am in the habit of treating it as a sign of probable fracture when, from the circumstances of the case, the other and more positive signs are not to be certainly expected, as in some fractures at the lower end of the radius or of the tibia or fibula. In like manner a localized pain, excited by slight communicated rotatory movements of the limb at a point in the shaft of a long bone where there is no contusion, is a sign of probable fracture. Malgaigne says he has on several occasions seen a diagnosis of fracture made upon this symptom alone confirmed by the subsequent course of the case.

The *history* of a case, with reference to the diagnosis, includes earlier injuries which may have modified the form of the limb, the nature of the accident and the method of fracture, and occasionally the snap heard by the patient or bystanders at the moment the injury was received. The latter is probably produced very commonly, but as a rule it passes unperceived because the attention of the individual is occupied by the fall or the impending blow which causes the fracture. Consequently it is more commonly observed in fractures by muscular action than in others. As a similar sound may be caused by the rupture of a tendon the absence of this latter lesion must be established before the diagnosis of fracture can be made simply upon the occurrence of an audible snap at the moment of the accident.

Reasons have been given already to show why it is necessary to make inquiries concerning previous injury to the limb, so as to avoid an error in diagnosis; the danger to be avoided is that of supposing a pre-existing deformity to have been produced by recent violence which has really caused only a contusion or sprain at the seat of a former injury.

A knowledge of the mode in which the injury has been received is of importance in determining the diagnostic value to be attached to some of the symptoms previously described, especially those of pain, ecchymosis, and swelling; and when, as is frequently the case, the patient is unable to say positively what portion of the limb received the blow, an examination of the surface may show an abrasion or contusion or a stain left by contact with the ground which indicates the point in question. If a limited point of pain, or of greatest pain, is then found at a distance the existence of a fracture by indirect violence is probable, while if the pain is found only at the spot where the blow was received its diagnostic value is less. The degree of the causative violence is of less importance, in view both of the difficulty of correctly estimating it and of the varying fragility of the bones which often makes fracture possible by slight causes.

These are the facts upon which a diagnosis must be based. As a general rule, they should all be sought for systematically, even when the diagnosis is not obscure, because it is only by this means that the surgeon can acquire the necessary familiarity with them which will make it possible for him to recognize them in doubtful cases. When the surgeon

is called to a case of suspected fracture he should begin his examination by inquiring into all the circumstances of the injury, not only for the purpose of giving the patient time to recover from the excitement produced by his arrival and the dread of a painful examination, as Prof. Hamilton has wisely urged, but also to obtain the information which he may need later when the patient is, perhaps, under the influence of an anæsthetic.

In proceeding to the direct examination of the injured part, the importance of avoiding all needless pain and rough handling must be kept constantly in mind; the clothing is first removed, in doubtful cases from the opposite limb as well as from the injured one, and the part inspected for the discovery of any contusion, ecchymosis, swelling, or deformity recognizable by the eye. If a deformity is found its extent may be determined in suitable cases by measurement. Then the fingers are lightly passed along the course of the bones which may be the seat of the injury, in search of a painful point, or of any irregularity in outline; if the injury is in the vicinity of a joint, the ends of the bones which form it are carefully explored, their relations to each other compared with those of the corresponding bones on the opposite side, and the functions of the joint examined by communicating cautious movements to it.

Crepitation and abnormal mobility are next to be sought for by the methods heretofore described, and an anæsthetic employed if necessary.

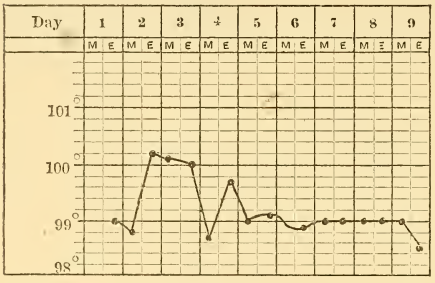
If a fracture has been detected, and if it is associated with a wound of the soft parts that probably makes it compound, the wound may be explored, preferably with the finger, for the purpose of determining the character of the fracture and of removing loose splinters of bone; but this is an exploration that should never be lightly undertaken, and in making it the surgeon should feel that he may, perhaps, do the patient harm that will not be fully compensated for by the information he obtains.

CHAPTER VI.

REPAIR OF FRACTURES.

The clinical phenomena which accompany the healing process after fracture of a bone vary with its character, and especially with its complications. In the simpler cases, when the injured limb has been properly secured by splints and bandages, the patient is usually free from pain and fever; he eats and sleeps well, disturbed only by the confinement to which he is subjected, and by more or less vague sensations of weight and uneasiness in the limb, or, perhaps, occasionally by involuntary twitchings of the muscles. A few blebs may form on the surface of the limb, but seldom cause any uneasiness. During the forty-eight hours immediately following the receipt of the injury he usually shows some rise of temperature, but it seldom reaches any great height or lasts long. A number of thermometrical observations in simple fractures, unaccompanied by much displacement, were made by Dr. Stickler[1] and Dr. Root, in my services at the Presbyterian and Bellevue Hospitals, and showed as light rise always. The accompanying thermograph, fig. 58, is from one of Dr. Root's cases, a simple fracture of the leg. Within a few hours after the receipt of the injury the limb swells, especially in the neighborhood of the fracture, and this swelling may be accompanied by puffiness of the corresponding hand or foot, due to interference with the return circulation. The swelling diminishes in a few days, and then a firm, rounded mass can be felt about the bone at the point of fracture, which is tender on pressure, and, during the following weeks, becomes gradually smaller and harder. As this mass hardens the abnormal mobility, which may have been noticed immediately after the injury, diminishes, and finally disappears, and the union is then complete, although not so strong as it will subsequently become. The hard mass which has effected the union continues to diminish for months afterwards, perhaps for years, so that in the simplest cases where, for example, the periosteum has not been torn, no trace of it will remain; but usually it can be detected after scraping the bone, or sawing it lengthwise.

Fig. 58.



Thermograph in a case of simple fracture of the leg.

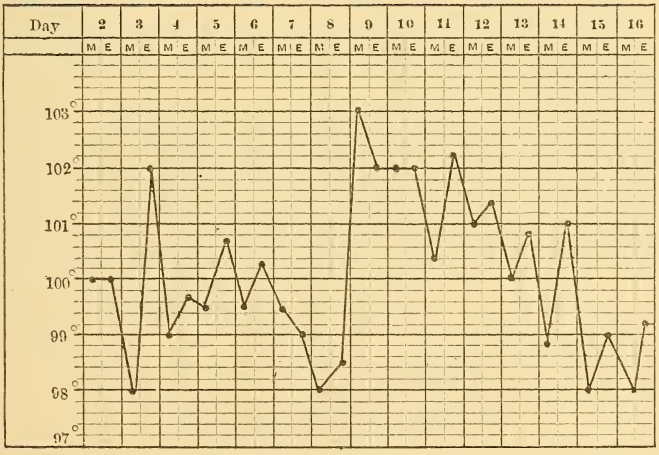
[1] N. Y. Medical Record, 1882.

In the severer cases, those marked by more displacement of the fragments, shattering of the bones, and violence of the reaction, the same sequence of phenomena is presented, but there is more pain, more swelling, and more general disturbance of the system. It has also been recently observed by Riedel (Deutsche Zeitschrift für Chirurgie, vol. x. p. 539) that in these cases and also in the less severe ones, albumen and casts are present in the urine during the first few days following the injury, and he describes in particular a kind of cast not found in the common diseases of the kidney, a brown granular cast of medium size. He attributes this intercurrent nephritis and the fever to the absorption of the serum of the blood extravasated and coagulated at the seat of fracture. He also found free fat in the urine in 42 per cent. of the cases examined.

The greater the displacement of the fragments and the consequent laceration of the soft parts at the time of the injury, and the more acute the onset of the inflammatory processes, within certain limits, the larger will be the mass (callus) which forms at the seat of fracture, both temporarily and permanently, and the greater the permanent deformity.

Usually the symptoms do not long remain acute, the œdema and redness diminish, the skin assumes a yellow color for a considerable distance on all sides, especially towards the trunk, the bandages are found loose at the daily examination in consequence of the subsidence of the swelling, the patient loses the pain and malaise previously felt, he eats and sleeps well, and convalescence is fairly established. But if some cause of irritation persists, if the tissues are constantly subjected to fresh laceration by the unreduced fragments kept constantly in motion by the involuntary contractions of the muscles or the delirious agitation of the patient, the prognosis becomes less favorable because the processes of the first stage are then more likely to terminate in suppuration instead of resolution. This suppuration may be confined to the seat of the fracture, the

Fig. 59.



Simple fracture becoming compound on the 9th day.

ends of the fragments lying bare in the cavity of the abscess, or it may spread up the limb accompanied by sloughing of the connective tissue and the formation of abscesses at various points, the deadly *acute purulent infiltration* of the older writers. Gangrene of the skin over the fracture may occur during the earlier stages as the result either of the direct violence that caused the fracture or of the pressure of a displaced fragment. Finally, nervous symptoms may make their appearance, either as an attack of delirium tremens within the first few days or as tetanus at a later period.

The progress of a case may be modified in an important manner by articular complications having their origin in direct communication between the fracture and a neighboring joint or in the extension to the latter of the inflammatory processes set up by the main injury. In the former case the symptoms pointing to the implication of the joint appear very promptly, the synovial sac becomes distended by an effusion of synovia mixed with blood in greater or less proportions, and pain on motion is extreme and referred directly to the joint. The injury, especially if the joint is a large one, is much more severe than a simple fracture and has a correspondingly greater effect upon the general condition of the patient; his temperature rises, his pulse quickens, and his digestion becomes disordered. The arthritis persists for several weeks, even under favorable circumstances, and either terminates in resolution after gradual abatement of the symptoms and with loss or diminution of the functions of the joint, due in part to changes in the relations of the surfaces to each other, or it goes on to suppuration and puts the life of the patient in peril. In some cases, as in fracture of the neck of the femur, union may fail entirely, and in others it may be fibrous instead of bony, results which, however, are not associated with any material change in the early clinical history of the case.

When the arthritis is the result not of a direct implication of the joint in the fracture, but only of an extension to it of the inflammatory processes set up by the injury its course is less severe. The joint becomes distended by an effusion of synovia, and pain, both spontaneous and on motion, is felt in it, but the consequences are usually limited to the formation of adhesions and peri-articular thickening. Suppuration follows only in rare cases.

In compound fractures the same series of phenomena is observed as in simple fractures, modified more or less by the coexistence of the wound. The liability to destructive inflammatory processes, to suppuration at the seat of fracture, to burrowing of pus, and to the other complications above mentioned is much greater, but as it is sometimes possible to obtain prompt union of the wound and thus transform the fracture into a simple one the course may be as mild and free from complications as in the other class of cases. In other cases the wound remains open on the surface but its deeper parts unite, and thus the transformation into a simple fracture is again accomplished and the course is as mild as before with such slight modifications as are due to the coexistence of a superficial wound. If union is not obtained, if the wound suppurates, the suppurative process extends to and involves the bone, giving rise either to a mild, uncomplicated osteitis marked by moderate fever, more or less

abundant suppuration, and formation of abscesses in the neighborhood, or to an acute osteo-myelitis ushered in by a chill, accompanied by high fever, and likely to terminate fatally by septicæmia or pyæmia. In the commoner class of cases, those in which the seat of fracture suppurates but in which the dangerous septicæmic complications do not appear, the general condition of the patient is not much affected. After the suppuration is fairly established the fever disappears so completely that any subsequent rise of temperature is to be regarded as an indication that something unusual or irregular is occurring in the wound, that drainage is imperfect, or that a new abscess is forming. The callus forms rapidly and exuberantly, the wound fills up but is slow to close, and fistulæ leading down to loose splinters or to necrosed portions of callus whose vessels have been obstructed by condensation of the tissue may persist indefinitely.

Among the symptoms peculiar to this variety are the projection of the bone through the wound and hemorrhage. The latter may be either arterial or venous, primary or recurring, and so profuse as to place the patient's life in immediate danger. A condition of collapse or shock, marked by palor of the surface, small pulse, nausea, restlessness, and, perhaps, a sighing respiration, may either be produced by this loss of blood, or may be the manifestation of the injury done to the nervous system or the abdominal viscera by the original violence, which in these extreme cases is far in excess of that usually concerned in the production of simple fractures. This condition may be followed by reaction, or it may persist until death closes the scene, after a few hours.

The period of time necessary to the repair of a fracture varies with the age of the individual, the bone involved, and the nature of the fracture; and the time at which the restoration of the functions of the part can be pronounced complete is always remote, and often is never reached. Malgaigne says that bone for bone, and fracture for fracture, repair in children requires only half as much time as it does in adults, and that except for this neither age nor sex presents any differences, an opinion that has been accepted by subsequent writers. He also says that the bones of the lower limb require more time for repair than those of the upper limb, and the latter more than the bones of the face; a fracture near the middle of the shaft unites more slowly than one at the extremity of the bone, and a fracture with permanent displacement more slowly than one in which the fragments are retained in their normal relations to each other. Union may be delayed far beyond the usual time by exceptional conditions, which will be considered in a subsequent chapter, such as the interposition of a portion of muscle between the fragments, or by constitutional affections, or occasionally under circumstances where the cause cannot be recognized.

Even after firm union has taken place between the fragments there remain changes in the limb, disabilities or weaknesses, whose slow disappearance prolongs the period of convalescence, or whose permanence renders a complete return to the condition existing before the fracture impossible. The limb is usually shrunken, and its muscles wasted and feeble; the skin is dry and has a tendency to become congested on slight provocation, such as exposure to the air, or a dependent position. There

is stiffness of the hand or foot of the broken limb, especially of the latter after walking; the neighboring joints are stiff and tender in consequence of the prolonged immobility and of adhesions formed within them or the sheaths of the tendons; and this stiffness and tenderness may persist until the end of life in the old and arthritic, even when the joint has not been directly involved in the injury.

Anatomo-pathological Processes.—Bone is one of those tissues whose cicatrices are composed of a substance closely resembling, or identical with, the original tissue. The ends of a broken bone become reunited by bone, and this new bone is formed out of materials furnished by the bone itself, its marrow and periosteum, and the adjoining soft parts. The phenomena which accompany and are instrumental in producing this repair have been known more or less completely since observation and experiment took the place of pure speculation in medical science, but the diversity in the views held concerning their origin, nature, and purpose has been extreme, and exists, in a measure, even at the present time, although accurate and well-devised experimentation, aided by perfected means of observation, has resolved most of the problems and harmonized much that was contradictory. A brief account of the stages through which the study and teaching of the subject have passed seems desirable, to enable the reader more easily to fit that which is new on to that which is old, and to interpret and use the terms and observations of the older classical writers in the light of our more precise and detailed knowledge.

The speculative theories of the ancients do not need mention beyond the fact that Galen's, which attributed repair to a "bone-juice" poured out from the broken ends of the bones, was the one generally accepted at the end of the seventeenth century when direct observation and experiment upon animals were first employed, and the real study of the subject began. Antonio de Heyde[1] recorded, in 1684, the conclusions he had drawn from experiments made upon frogs; he thought that the callus was formed by the solidification of the blood poured out between the fragments. Du Hamel,[2] experimenting upon pigeons and sheep, and interpreting the facts in the light of previous study of the method of repair in trees (he seems not to have been a physician, and certainly not a surgeon), formed the opinion that the periosteum, aided somewhat by the marrow, was the active agent of repair. His observations were numerous and accurate; he noticed the new formation of bone under the periosteum for some distance from the fracture and the smoothness of the bone wherever the periosteum had been stripped from it; also the tumefaction of the periosteum and the interposition of a thin gelatinous layer between it and the bone. He even placed, as all do now, the especial osteogenetic quality only in the innermost layer of the periosteum, or in the gelatinous layer just mentioned which adjoins and is produced by it, and attributed to them the normal growth of a bone in thickness,

[1] Ex his experimentis forsan probatur callum generari e sanguine evasato, cujus fluidis particulis sensim exhalantibus reliquum ossis formam assumit, quod promoveri potest ab halitu ex ossis fracti extremis deciduo. Quoted by Du Hamel in Histoire et Mémoires de l'Académie Royale des Sciences, 1741, p. 222.

[2] Hist. et Mém. de l'Acad. Royale des Sciences, 1741, pp. 97 and 222, and, 1743, pp. 69, 87, 111, and 288.

comparing it to the growth of a tree by the formation of wood under the bark. He denied that the cortical layer could reunite, and having in one case found a union so perfect that he could not trace the line of fracture after having sawed the bone, he boiled the specimen in a strong solution of lye, and had the satisfaction of seeing it fall into two pieces and thus confirm, as he supposed, his opinion. He claimed also that the lamellæ of the spongy tissue and on the border of the marrow were covered by a membrane that had its origin in, and possessed the functions of, the periosteum. In fact, he anticipated by one hundred years the discoveries of Syme, Heine, and Ollier, although it was left to these latter experimenters to furnish the actual demonstration.

A few years later, 1748–1767, Haller, Boehmer, and Detleef opposed Du Hamel's views, and reasserted the former theory of the "bone-juice"; according to them this juice was poured out by the bone, became gelatinous, then cartilaginous, and finally bony; and at about the same time an opinion first published by Jean Louis Petit, to the effect that the callus is formed by granulation tissue, as a cicatrix of the soft parts is, was again put forward and warmly defended by Bordenhave and others.

About a hundred years after the publication of De Heyde's experiments, his theory that the callus had its origin in the blood poured out between the bones at the time of the fracture, was revived by John Hunter, and thoroughly elaborated a few years later, with the aid of experiment and microscopical examination, by Howship,[1] whose descriptions are remarkably accurate and detailed, although his interpretation of the facts was erroneous.

Of these theories all except the one last mentioned are partly true, and together they furnish the basis of all subsequent ones. They erred because they were too exclusive or too indefinite, but being based upon experiment and observation they furnished sound data for speculation, and indicated new lines of research, which have since been freely used by theorizers, or followed out by investigators. The main facts, as far at least as the gross appearances were concerned, were fairly before the profession at the beginning of the present century, and upon them and the pathological and clinical facts furnished by his large experience Dupuytren constructed his theory of the development of the callus, a theory complete in all details, logical in its development, seductive in its fulness and verisimilitude, lacking only in accuracy. As the terms and, in a measure, the ideas of this theory are current at the present time, it requires description.

Dupuytren brought again into prominence Du Hamel's theory of the part played by the periosteum, a theory which had been almost lost sight of in the general acceptance, under the able advocacy of Bichat and Scarpa, of that of repair by granulations springing from the broken bones, and extended it by attributing the same power to the adjoining soft parts when the exercise of that power was necessary. He described two calluses, the one temporary or "provisional," the other permanent or "definitive." The former was composed of two parts, the voluminous ovoid mass of spongy bone that incloses and binds together the

[1] Med. Chirurg. Trans., 1818, vol. ix. p. 143.

broken ends of the bone and to which the name "ensheathing callus" has been given by the English authors, and a central bony plug uniting the two portions of the medullary canal. The broken bone itself, that is, its compact layer, did not share, according to Dupuytren, in the production of this callus and had no immediate union with it; the fragments were simply imbedded in a mass of spongy bone produced by the joint action of the marrow, periosteum, connective tissue, and even the muscles themselves, which made up by its bulk for its lack of compactness and kept the pieces immovable until a small bond of firm, compact bone, the *definitive callus*, had formed between and restored the direct continuity of the cylindrical shell. He divided the period of formation and development into five stages[1]: 1st, the stage of irritation, lasting until the eighth or tenth day, during which extravasations of blood take place between the fragments and into the adjoining tissues, the connective tissue swells and becomes more firmly united with the periosteum and muscles, the marrow thickens, and a viscid substance or a mass of pink granulations fills the space between the fragments; 2d, the cartilaginous stage, lasting until the twentieth or twenty-fifth day, during which the external callus is formed from the periosteum and soft parts and is transformed into cartilage, the change beginning in the centre and extending outwards, and the medullary canal is closed by a bony plug formed within it; 3d, the stage of spongy ossification, lasting until the fiftieth or sixtieth day, during which the provisional callus is completed by its transformation into spongy bone; 4th, the stage of compact ossification, lasting until the fifth or sixth month, during which the substance between the fragments, which appears as an interposed line of different color, grows firmer and whiter and is finally changed into compact bone, establishing firm union between them; 5th, the stage of disappearance of the provisional callus, lasting until the tenth or twelfth month, during which the external callus and the medullary plug are absorbed.

All subsequent theories and descriptions of the process of repair are modifications or amplifications of one or more of those above mentioned, so far as the origin and nature of the process are concerned, and owe their individuality to the importance given by them to one or the other element in the process or to the effort to establish differences based upon the degree and character of the displacement of the fragments. The discrepancies are more apparent than real, and the observed clinical differences can all be referred to variations in one and the same fundamental process, variations imposed upon it by the relations of the periosteum and fragments to each other.

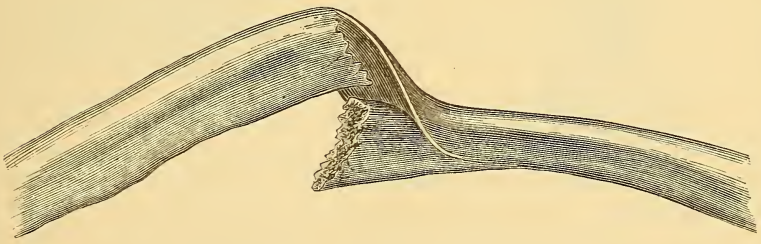
The process of repair after fracture is fundamentally the same as that of repair after other injury, and its phenomena differ only in degree from those of normal nutrition and growth of bone. It is the normal nutritive process exaggerated by the irritation of the traumatism, and as such involves all the constituent parts of the bone. It begins with the multiplication of the cellular elements of the periosteum, marrow, Haversian canals, and lacunæ of the spongy tissue; this multiplication produces a mass of granulations which fill the gap between the fragments and are

[1] Leçons orales de clinique chirurgicale, vol. ii. p. 49.

transformed into bone, sometimes directly, sometimes after having passed through a cartilaginous stage. This mass of new bone, at first spongy in its structure, that is, composed of irregular lamellæ or plates circumscribing relatively large lacunæ filled with bloodvessels and medullary elements,—becomes firmer and more compact in some portions by increase in thickness of the lamellæ and consequent reduction in size of the lacunæ, the process known as "condensing osteitis," a stage of productive osteitis, and observed constantly in the fœtus as well as under many pathological conditions, and becomes thinner and weaker in other portions until it finally disappears by the converse process, diminution of the lamellæ through their absorption by the medullary elements of the lacunæ, "rarefying osteitis," another stage of productive or simple osteitis and also found in the normal development of a bone and in pathological conditions. There is nothing in the process more mysterious than this, nothing that requires the intervention of a special Deus ex machinâ, nothing that distinguishes it fundamentally from that of the repair of any other member of the great group of the connective tissues. The variations depend upon differences in the degree of the injury or in the position of the fragments, which require disproportionate amounts of work to be done by the different parts. The details of the process will appear upon examination of the manner in which it is carried on after simple fracture of the shaft of a long bone, an example which has the advantage of illustrating the behavior of all the different elements and of being both more complete and more open to experimental study than fractures of short bones or of the spongy extremities of long ones.

When a fracture takes place the cylindrical shell is broken along an irregular line and probably always with the production of splinters of greater or less size. The marrow is bruised by the pressure of the broken ends as they slip past or are driven into each other. The periosteum is usually torn, but the extent of its rupture has probably been largely overestimated even when there is much displacement of the fragments. Ollier[1] was the first to call especial attention to the preservation of its continuity at some part of the periphery of the bone, and to the

Fig. 60.



"Periosteal bridge" after fracture of a rib.

fact that when a lateral or longitudinal displacement has occurred the membrane is stripped partly off one fragment, but without having its continuity broken, and thus forms a band uniting the two fragments. To

[1] Traité de la Régénération des Os.

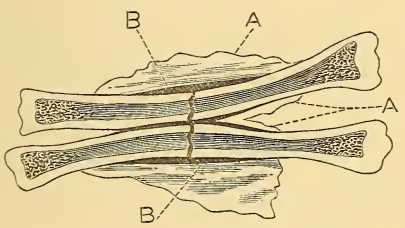
this band he gave the name of "periosteal bridge." Fig. 60 represents a periosteal bridge of this kind as I found it eight days after the fracture of a rib. The same rib showed at another point of fracture the periosteal envelope complete except for a distance of one-fourth of an inch. The patient was an old man and the fractures were caused by a fall from the fourth story of a house. In another case, an extensive depressed fracture of the skull in a lad of 17, I found the pericranium untorn but separated from the bone over the entire area of the depression by effused blood. In compound fractures with protrusion of a fragment it is common to find the projecting end and other portions accessible to the touch denuded of periosteum; and remembering also that the periosteum is rather loosely attached to the bone and, on the other hand, is continuous by an intimate structural union with the overlying soft parts, I am inclined to believe that its continuity is largely preserved in all cases, or that if temporarily destroyed at some points by perforation by a fragment it is practically restored when the displacement is corrected. The observed liberty of motion is given to the fragments by the stripping up of the periosteum from one or both of them, and the extent of this denudation depends upon that of the displacement. This being so, the periosteum would furnish a tubular sheath connecting the ends of the fragments and all splinters except those that are entirely loose, guiding and limiting the formation of the new tissue that is to establish the ultimate union. Whether this sheath is complete or not, the existence of the periosteal bridge indicated by Ollier is of extreme importance because it maintains the connection between the fragments by means of a tissue whose activity in the production of bone is abundantly established. The position and form of the callus in numerous specimens of union with displacement have seemed to me to indicate clearly the position and agency of a periosteal bridge.

At the same time blood is poured out from the torn vessels of the bone into the gap between the fragments, and from the vessels of the adjoining soft parts into the interstices among the muscles. This blood is gradually absorbed during the first few days following the receipt of the injury, and at the same time the effects of the traumatism are manifested in the usual inflammatory œdema of the limb and the infiltration of a thick viscid liquid into the soft tissues immediately adjoining the seat of the fracture, the beginning of the firm ovoid mass which can always be felt at this point. The periosteum becomes much thicker, softer, and more vascular, a thin layer of gelatinous or viscid liquid is found between it and the bone for the distance of a few lines from the edge of the fracture or from the point to which the membrane has been stripped up, and at the more distant limit of this layer the surface of the bone promptly becomes roughened by the formation of patches of new bone. The portions of the periosteum which have been stripped off, those which form complete or incomplete periosteal bridges, and the lacerated tissues which form the wall of the cavity in which the ends of the bone lie granulate and pour out lymph into this cavity to mingle with the partly coagulated blood remaining there.

The marrow shares in this production of granulations; and the cells of the connective tissue external to the periosteum share for a greater

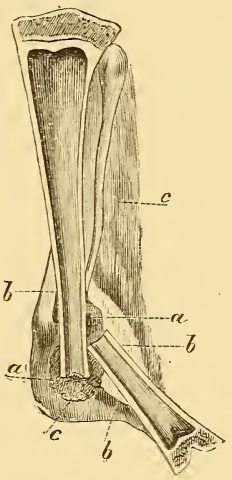
or less distance in the irritation and by their proliferation bind together all the adjoining parts, muscles, tendons, and fasciæ, in one firm, compact mass. The compact layer of bone, the cylindrical shell of the shaft, feels the same influence and reacts in the same manner, but much more slowly in consequence of the scantiness of its available cellular elements. Its surface and that of its broken ends soon show pink points which enlarge and send out granulations to join those already produced by the periosteum and marrow, and thus there is formed between the separated fragments a bond of union which is actually continuous, almost from the beginning, with all their constituent parts. It has no strength, no ability to resist an external strain, such as is possessed by bone ; that strength will be given to it by ossification, but meanwhile its weakness is supplemented by the inflammatory tumefaction of the neighboring parts which impedes the movement of the fragments, and by the enforced rest to which the limb is condemned by the nature of the injury. The size and character of this bond vary with the degree of displacement ; if the fragments remain nearly in their original relations to each other the bond is short and symmetrical, the granulations springing from the marrow meet and unite in the centre of the gap, while the thickened periosteum passes directly from one fragment to the other, remaining adherent to them or separated only by a layer of effused blood. If longitudinal and lateral displacement occurs and persists the bond passes obliquely from the outer surface of one fragment to that of the other and is much more complete at some points of the periphery than at others. Thus, in figure 62, which represents the condition found by Gurlt on the seventh

Fig. 61.



Callus of a pigeon's bone on the 6th day. (Du Hamel.)

Fig. 62.

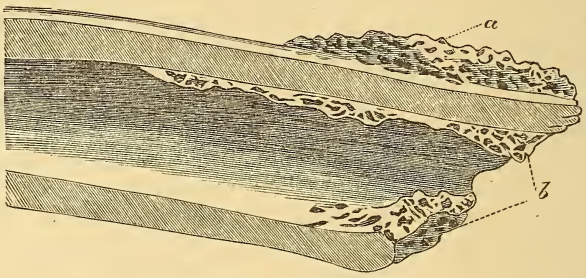


Tibia of rabbit, 7th day : *a*. blood ; *b*. cartilaginous callus; *c*. muscles. (Gurlt.)

day after fracture of the tibia of a rabbit, the firmest union is by the cartilaginous band crossing the angle at *b* and formed apparently by the thickening of a periosteal bridge. On the opposite side of the lower fragment the beginning of an incomplete band of similar structure is seen.

The formative action thus begun is rapidly carried on, and principally by the periosteum and marrow. When the fragments are kept end to end an ovoid mass of tissue having the consistency of jelly and a pearly white appearance, and continuous above and below with the periosteum, envelops them, the so-called "ensheathing callus." This mass is formed

Fig. 63.



Callus on the 15th day. (Howship.)

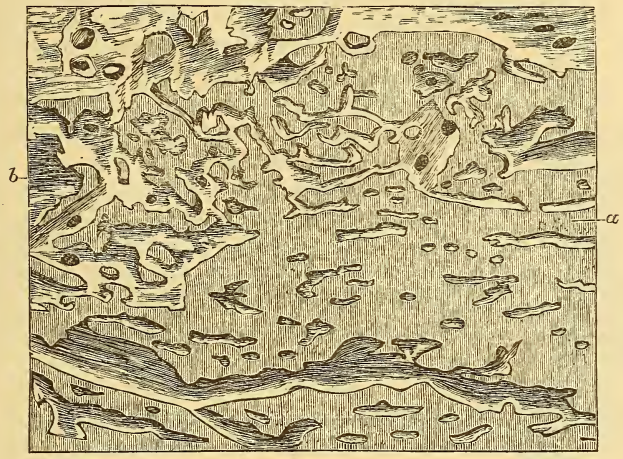
not solely by granulations springing from the under side of the periosteum, but also by the thickening of the connective tissue on the outer side, including even that which surrounds the adjoining muscular bundles and fibres. Composed at first of embryonal elements, it soon becomes cartilaginous; then lime salts are deposited at different points within it, and finally it is transformed into bone.

The granulations that spring from the marrow ossify without passing through the cartilaginous stage, and the process here apparently begins, as in other pathological conditions, at the fine lamellæ which lie upon the inner side of the compact shell. The new lamellæ extend across the canal, soon occluding it entirely, and also out into the interval to meet those coming from the other fragment. Thus is formed the internal or medullary plug.

The granulations lying in the annular interval between the two portions of the compact tissue, the "intermediate substance" which, according to Dupuytren, was to form the definitive callus, ossify as the rest do after passing through the cartilaginous stage, and become united to and continuous with the compact tissue, but they originate in the periosteum or the adjoining subperiosteal layer. The lateness of this union, which does not become firm for several months, is due to the slight vascularity of the compact tissue, to the small size and limited number of the channels in which the bloodvessels and cellular elements are contained. The capillaries which open upon the surface of the fracture are occluded by coagulation, and the cell proliferation which begins behind the clots can make its way to the surface and form granulations there only after absorption of a certain amount of the bone itself. This absorption takes place either along the sides of the channels (Haversian canals) leading directly down to the surface of the fracture, or along a line parallel to this surface; in the latter case a scale of bone is separated or "exfoliated," as is often seen in a compound fracture or after an amputation or resection. In a simple fracture such a scale, if formed, probably undergoes complete absorption, or perhaps may be imbedded in the callus

as splinters of larger size sometimes are. The compact tissue, therefore, has to pass through a preliminary or preparatory stage of rarefying osteitis which approximates its structure to that of the spongy bone of the callus, so that at a certain time we find on longitudinal section through the two fragments and the callus that the original compact tissue on each side becomes gradually more and more spongy or vascular as the line of fracture is approached, shading off into the callus in such a manner that this line can scarcely be recognized. Ultimately this spongy bone is

Fig. 64.



Callus and adjoining rarefied bone. (Howship.)

made denser by the deposit of new bone on the surfaces of the lacunæ and the consequent diminution of the latter, and thus its structure becomes more nearly identical with that of the compact tissue, although it never presents the same regularity and symmetry in the size and arrangement of its canals.

Fragments of the cortical layer broken off at the time of the injury may remain attached to the periosteum, preserve their vitality, share in the same processes, and form a part, often an important one, of the callus. There is reason to believe also that even after they have been entirely detached they may form new connections with the soft parts and granulations, and preserve, perhaps even renew, their life. Such fragments have been found imbedded so deeply in a callus that no other explanation than that of complete detachment can well be accepted. Howship describes and figures one, and Gurlt another and very remarkable one, figure 65. Quite recently the possibility of this preservation has been established by experiment upon animals. Portions of the shaft of a long bone have been chiseled off, separated entirely from the soft parts, and replaced in contact with the bone; the wound of the soft parts united promptly under antiseptic treatment, and subsequent examination after the lapse of a sufficient period of time showed reëstablishment of vascular connection and preservation of the vitality of the fragments.[1]

[1] Centralblatt für Chirurgie, 1880, No. 44.

Bergmann presented at the 10th Congress of the German Gesellschaft für Chirurgie[1] a specimen of gunshot wound of the knee-joint in which a fragment of the external condyle of the femur had been driven into the crucial ligament and had healed there; the length of time that had elapsed since the receipt of the injury is not given. The patient died of dysentery.

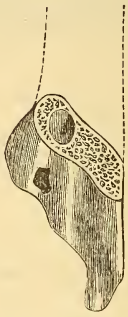
Fig. 65.

Fracture of the neck of the femur and of the shaft. A splinter, *a*, 5 inches long and nearly 1 inch wide, composed of the cortical layer, has been turned completely about its long axis and become united, with its original periosteal surface in contact with the other fragments. (Figured by Gurlt from the Museum of the Royal College of Surgeons, England, No. 454.)

It is also known that fragments may long remain without vascular connection imbedded in a callus as well-tolerated foreign bodies. After the lapse of months or even years, and from unknown causes, they sometimes cause irritation; an abscess forms, the bone softens about them, and either they are cast out spontaneously or they remain, provoking an interminable suppuration, until removed by the surgeon. This is frequently observed after gunshot fractures.

It occasionally happens that the callus does not ossify, and in some very exceptional cases the bone is entirely absorbed for a very considerable distance on each side of the seat of fracture. The causes are not fully understood. The difference in the process consists in an entire or partial absence of productive osteitis, and in an excess of the rarefying osteitis; the consequence of the former is the development of the granulations into fibrous tissue, with occasionally an irregular outgrowth from the end of the bone; that of the latter is loss of substance of the bone itself, reducing its thickness or its length, and sometimes causing it to terminate in a point. Figure 66 represents a portion of bone which I removed in an operation for pseudarthrosis of the humerus; it shows a central cavity formed within the bone, a perforation near its lower edge, and a considerable prolongation of one angle. The end of the lower fragment was conical.

Fig. 66.



Portion of humerus removed in an operation for pseudarthrosis.

[1] Beilage zum Centralblatt für Chirurgie, 1881, No. 20, p. 14.

In a second variety of pseudarthrosis the fibrous bond extends not as a solid cord between the fragments, but as a cylindrical one, similar to the capsule or ligaments of a joint, and the ends of the bones become eburnated, smooth, and rounded by friction upon each other, or covered by a layer of cartilage.

The diminution of the callus and the rounding off of projecting points or ends, which take place slowly during the months following the injury, are effected by a continuation of the same process of rarefying osteitis which begins so early and prepares the bones for union. Sir James Paget[1] mentions a case in which the size and prominence of the absorbed portion of bone made it possible to observe the process in its different stages. "A patient in the Exeter Hospital had a bad comminuted fracture of the leg, and a long spike of the tibia, including part of the spine, could not be reduced to its exact level, but continued sensibly elevated, though in its due direction. At the end of five weeks (union having taken place) the end of the spike began to soften; at six, it was quite soft and flexible, like a thin cartilage; at the conclusion of the seventh week it was blunt and shrunken. Six months later, the cartilaginous tip had disappeared, and the spike was rounded off." The term "cartilaginous" must be understood to refer only to the consistency of the tissue, for no cartilage is formed in this retrograde process. The granulations are formed by the multiplication of the soft cellular elements lining the canals of the bone and develop directly into fibrous tissue.

When the fracture is compound the details of the reparative process are different to this extent, that the callus does not pass through the preliminary cartilaginous stage at any point where suppuration has occurred. The formation of the medullary plug is not affected, the granulations there being transformed directly into bone as they are in simple fractures; the difference is in the external or ensheathing callus. The reason of this difference as shown by experiment[2] lies in the destruction of the periosteum by the suppurative process, in the destruction, that is, of the only tissue whose granulations pass through the cartilaginous stage in forming the callus.

The process is slower than after a simple fracture because the suppuration of the wound delays or prevents the formation of much of the external callus and throws most of the labor upon the bone itself, which, as has been shown, is the least capable to perform it. It is easy to watch the process. The ends of the bone are seen lying bare and white in the wound; a mass of pink granulations forms at the limit of the denudation and advances slowly across the bared surface; the broken surface remains for a time quiescent, then granulations spring from it, beginning at the points nearest the medullary canal and spreading slowly towards the outer edge; the wound gradually fills up with these granulations, the bone is covered in, and cicatrization follows.

In less fortunate cases a portion of the bared bone dies and is cast off

[1] Lectures on Surgical Pathology, 3d ed., Phila. 1871, p. 191.

[2] Rigal and Vignal, Comptes Rendus de l'Acad. des Sciences, 1880, vol. xc. p. 1218.

by the formation of a line of demarcation which can sometimes be seen at the edge of the granulations but which more commonly is hidden by them. It must not be thought that all the bare white bone seen in such a wound is dead, even after it has remained unchanged in appearance for several weeks. Its surface may indeed be dead, but the interior is often alive and able to cast off the dead superficial scale without aid. The granulations that form between the living and the dead parts seem sometimes to dissolve and absorb the latter if they are small and thin, or, if not, to slowly bear them to the surface and cast them out.

The callus thus formed is larger and more irregular than after simple fracture; it remains tender and sensitive for a long time, and is covered by an adherent scar at the seat of the wound if the bone is superficial. Fragments formed at the time of the accident and remaining attached to the periosteum usually preserve their vitality; if not, they become detached after a time and are found loose in the wound, or become shut in by the callus and prolong the suppuration indefinitely. In this latter case the constant irritation due to the presence of the foreign body, the existence of sinuses, and the burrowing of the pus interfere with the evolution of the callus. Instead of undergoing a gradual and uniform diminution and condensation it becomes eburnated at some points and entirely absorbed at others, irregular prominences appear on its surface or follow the lines of attached tendons and fasciæ, and its interior is occupied by cavities of various sizes usually suppurating and in communication with the exterior. The walls of these cavities are sometimes carious, sometimes covered with feeble granulations that furnish a constant discharge and show no tendency to fill the cavity and ossify. Malgaigne extracts from the Mémoires de l'Académie de Chirurgie a case of gunshot fracture of the femur below the trochanter, the persistent suppuration from which caused the death of the patient in five years. All the sinuses led into a large cavity in the bulky and irregular callus, and this cavity was lined at all points by a thick, soft, whitish membrane, while the burrowing of the pus on the outside had denuded the great trochanter and rendered it and the hip joint carious.

In compound fractures, accompanied by much shortening of the bone and laceration of the soft parts, the inevitable suppuration of the latter is usually so prolonged and so extensive that most of the smaller fragments cannot preserve their vitality, and their loss creates a gap often too large to be filled by the new bone. The granulations become fibrous instead of bony, and the only union between the two ends of the bone is by a dense band of connective tissue.

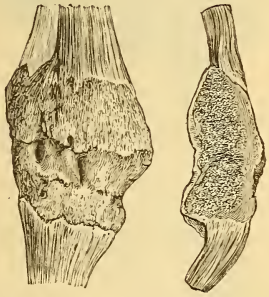
The duration of the process of repair after a compound fracture varies greatly, as may be inferred from what has already been said. If the external wound closes without deep suppuration the course is the same as that of a simple fracture; if, on the other hand, necrosed fragments become imprisoned in the callus the resulting fistulæ persist indefinitely. As a general rule, however, a much longer time is required for the establishment of firm union than after simple fracture.

In the short and flat bones which have no medullary canal, and in the spongy extremities of the long ones, the details of the process of repair are modified only by the absence of the marrow. The same granula-

tions form upon the broken surfaces of the bone, and the torn periosteum and soft parts unite and ossify. The external callus in the ribs is often large, because of the mobility of the parts, but in the other cases mentioned there is usually but little projection of the callus beyond the outline of the bone, probably because the displacement and laceration are less, and possibly, in part, because the periosteum, being more adherent than it is upon the shaft and more generally perforated by tendons and ligaments, is not stripped up to any great extent, but is torn directly through along the line of fracture. When the fragments are replaced the edges of the periosteum unite promptly and confine the mass of granulations within a narrower space than when this membrane has been stripped up and is held away from the bone by an interposed clot of blood. In short, the condition of the parts is more likely to be favorable to the work, for the surfaces of contact are broad, uniform in structure, and with a large proportion of spongy bone, from which the granulations can spring immediately without the aid of preliminary rarefaction, and the fragments are not liable to be disturbed by the involuntary muscular twitchings or movements of the patient.

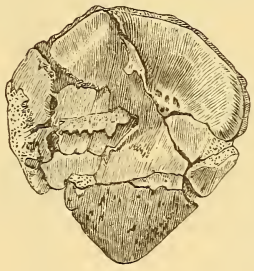
In fractures involving joints the form and origin of the callus are again modified by anatomical differences, of which the absence of periosteum and other soft tissues on the articular surface is the chief. The fracture communicates more or less freely with the cavity of the joint, and the synovia bathes the granulations and interferes with their devel-

Fig. 67.



Bony union of the patella. (Bryant.)

Fig. 68.



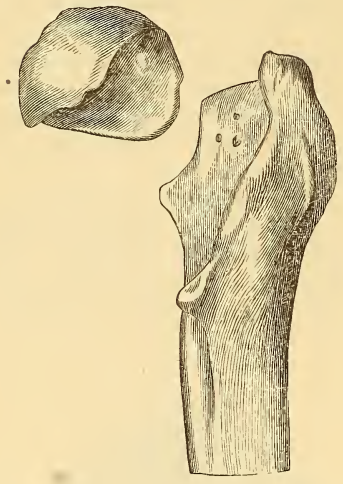
Comminuted fracture of the patella. Bony union. Exuberant callus at several points. (Gurlt.)

opment, as an excess of liquid usually does. The absence of periosteum on the articular surface prevents the formation of an external callus on that side, and union takes place by granulations arising directly from the fractured surfaces and by an external callus at the extra-articular parts of the fracture. To this extent the details are the same as in repair after fracture of the spongy bones, and the differences in result are mainly in the completeness of the union, which is often fibrous, and sometimes fails. When the conditions are favorable and bony union is obtained the line of the fracture is always marked on the articular surface by the absence of cartilage over it, and usually by a groove. The fracture of the cartilage does not heal by the formation of new cartilage; usually the callus is covered at this point by a firm, white layer of fibrous

tissue resembling in its gross appearance the cartilage with which it is continuous, but not having its structure, and sometimes the bone is bare. In exceptional cases the callus is exuberant and grows out beyond the level of the cartilage, forming an irregular mass in the place of the usual groove.

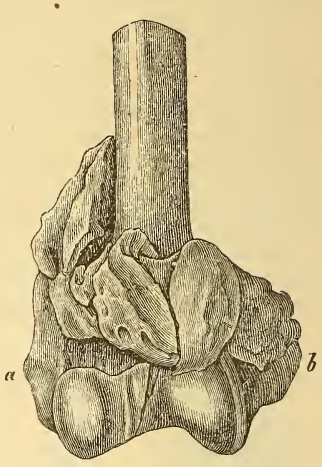
Failure of union, which is not rare in articular fractures, has been attributed exclusively, but apparently without sufficient reason, to the action of the synovia upon the granulations. The cause lies rather in the separation or the mobility of the fragments, and also, in cases where

Fig. 69.



Absorption of the neck of the femur after intra-capsular fracture. (Gurlt.)

Fig. 70.



Intra-articular fracture of the lower end of the humerus, with exuberant callus, especially in front.

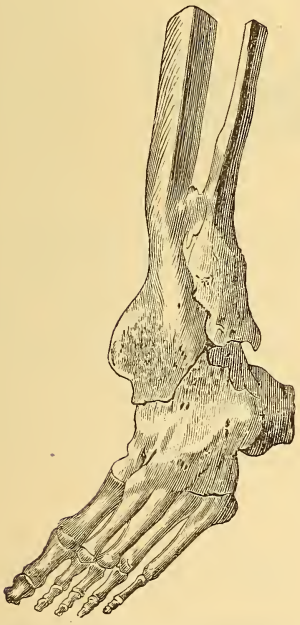
the fracture lies entirely within the cavity of the joint, as in intra-capsular fracture of the neck of the femur, to insufficient blood-supply, and to the absence of soft parts capable of forming an external callus to unite and steady the fragments while union is taking place between them. In extreme displacement, such as complete rotation of the head of the humerus after intra-capsular fracture of its neck, union must take place, if at all, between the broken surface of the lower fragment and the articular surface of the upper rotated one, and the materials for it must be furnished almost exclusively by the former, since the vascular supply to the other is carried on only by the vessels of such portions of the synovial sac as may have preserved their attachments to it. Partial absorption of the head, neck, and broken surface of the trochanter is common after fracture of the neck of the femur, and is effected by the rarefying process already described.

Exuberance of the callus, both external and intermediate, is a frequent cause of diminution of the functions of the joint by destroying the normal relations of the articular surfaces, by filling up normal depressions, and by creating abnormal prominences. These results are usually beyond

the control of the surgeon, and the latter are most common in the young, whose power of producing bone is greatest. Occasionally the productive process excited by the fracture extends far beyond the limits of the latter, and not only may the joint itself be entirely obliterated by fusion of the bones which constitute it, but the process may also spread to, and produce the same result in, neighboring joints, as in the case represented in fig. 70.

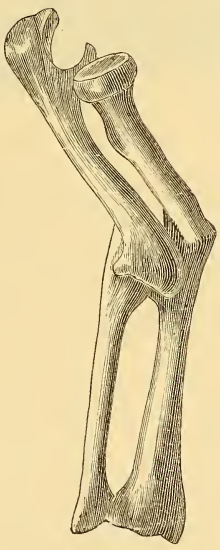
Bones which lie parallel and close to each other, as those of the forearm and leg and the ribs, may become united by an exuberant callus when either one or both are broken. This consolidation occurs most frequently when both bones are broken at the same level, and when the displacement of one or more of the fragments diminishes the normal interval between them. The lacerated soft parts granulate as has been described, the mass of granulations developed about one fracture becomes continuous with that developed about the other, and ossification follows. The presence of an interosseous membrane favors this undesirable result, for this tissue has the same tendency to ossify that is shown by other fasciæ and tendons in the presence of a productive osteitis. The effect

Fig. 71.



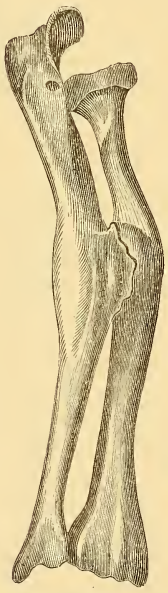
Bony ank losis of the foot and ankle after fracture of the leg. (Gurlt.)

Fig. 72.



Fracture of the forearm, angular displacement, and union between the bones.

Fig. 73.



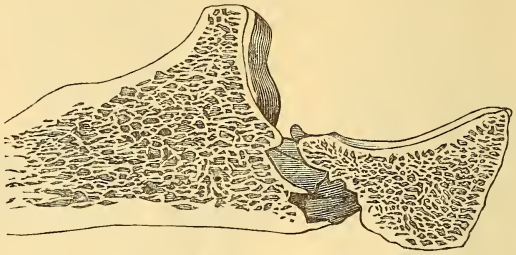
Fracture of the forearm, with formation of a lateral joint.

of this consolidation is, of course, to prevent independent motion of the two bones, and while of no importance in the leg and of little, if any, in the ribs, it produces a very serious disability in the forearm by causing the loss of the movements of pronation and supination. It occasionally

happens, when two bones are broken at the same level, that the calluses grow into contact with each other but do not unite. Their adjoining surfaces are smooth and together form a sort of lateral joint, which may allow movement of one upon the other. In the specimen represented in fig. 72, pronation and supination were lost, but the loss was apparently due as much to the angular displacement of the bones as to the exuberant callus.

Finally, separation of the fragments may lead to total failure of union, to fibrous union, or to insufficient union by a bony bridge. The latter is found in combinations of extreme longitudinal and lateral displacements, and differs from normal repair only in the insufficient formation or ossification of the granulations. Fibrous union is most common in the old, after fractures which have not been immobilized properly or for a sufficient length of time, and in articular fractures with separation, of which the most common examples are furnished by fractures of the patella and of

Fig. 74.



Fracture of the olecranon; fibrous union. (Malgaigne.)

apophyses to which powerful muscles are attached, as the olecranon or the coronoid process of the ulna. The tonicity of the muscle tends to draw the fragment away, and the latter is so small or so situated that efficient measures to counteract this action cannot be employed. The first steps of the process of repair may take place as usual and granulations form between the fragments, but they develop into fibrous tissue instead of bone, apparently because the ossific influence of the fragments from which they arise or to which they are attached cannot exert itself over the entire distance. In other cases the granulations seem to be furnished mainly by the soft parts, and their development is naturally into fibrous tissue rather than into bone.

When the line of fracture follows that of a still existing epiphyseal cartilage either wholly or in part, and the fragments are not displaced, union takes place apparently as readily as after simple fracture, but nothing positive is known of the details of the process. There is reason to believe that the injury does not necessarily interfere with the subsequent growth of the bone; the layer of cartilage may remain unossified and perform its functions as before; but it is known from the results of experiments upon animals and from some cases of inflammatory disease affecting the ends of the bones, that the effect of irritation of the epiphyseal cartilage is sometimes to hasten its ossification and thus arrest the growth of the limb. This last result must certainly be produced

when the epiphysis is dislocated by the fracture and is not restored to its place, and experience has shown the possibility of a similar arrest by premature ossification due to the irritation of a fracture. (See p. 51.)

Mr. Bryant[1] mentions a case of arrest of growth of the humerus amounting to three and a half inches following fracture of the shaft at the age of eight years, which he attributes to injury of the nutrient artery. Gurlt quotes a case of separation of the upper epiphysis of the humerus which showed, on dissection three years afterwards, a false joint between the fragments. The head of the bone was united to the neck of the scapula, and the movements of the limb were free.

[1] Surgery, 3d Am. ed., p. 833.

CHAPTER VII.

COMPLICATIONS AND REMOTE CONSEQUENCES OF FRACTURE.

Under this title will be described the traumatic complications that arise more or less promptly after fracture, although not peculiar to that class of injuries, and the later changes observed in the form and functions of the injured limb after union has been obtained, its occasional sensitiveness, and irregularities in the form and evolution of the callus.

A fractured limb is far from having regained its former appearance and its functions at the time when union between the fragments may first be said to be complete. It is shrunken, its skin dry, rough, and scaly. If a lower limb it swells and reddens when the patient begins to walk, the swelling being most marked and firm about the ankle; its joints are stiff and sometimes immovable, and it is often painful after use or during changes in the weather. These defects persist for a longer or shorter time, and some of them may be permanent.

Stiffness of the joints is observed not only in those articulations that have been directly involved in the fracture, but also in others at a distance. Sufficient mention has been made of the causes of the former in the preceding chapter; so far as the stiffness is due to permanent changes in the form of the articular surfaces and in the relations of the different parts of the joint to each other, changes which oppose a mechanical obstacle to the movements of the bones, it is practically permanent, and little, if any, improvement is to be expected. Occasionally the ligaments lengthen under forced use, or projecting surfaces of bone are in part absorbed, and the range of motion may thereby be slightly increased.

The cause of the stiffness that is so generally observed in contiguous joints not directly involved in the fracture, has been the subject of much controversy, and it is probable that there are several of them. Examination after death or after amputation of the limb, has frequently shown evident signs of inflammation of the joint: injection and thickening of the capsule, softness of the cartilage, and sometimes intra-articular bands of recent formation. Quite recently Gosselin and Berger[1] reported three autopsies which proved, they claimed, that this arthritis is due to the passage into the joint of extravasated blood coming from the fracture. This opinion was considered much too exclusive by their colleagues in the Society, although possibly correct in some cases. The arthritis, which is especially common in the knee after fracture of the leg or thigh, presents two clinical forms; in one it occurs immediately after the injury, in the other only after the lapse of a few days. The first is undoubtedly due in some cases to an associated sprain, in others possibly to the causes

[1] Bulletins de la Société de Chirurgie, 1878, pp. 6 and 336.

described by Gosselin and Berger; the second is the result of the extension employed to overcome or prevent shortening. Malgaigne attributed the stiffness in the knee to the extended position of the joint and to retraction of the ligamentum patellæ, and fortified the opinion by reference to the rarity of stiffness in the elbow after fracture of the shaft of the humerus, which is habitually treated with the forearm flexed. But it is undeniable that the same stiffness is found after treatment of fracture of the thigh in the flexed position, and is absent when the limb is immobilized in extension for other reasons than fracture, and therefore Malgaigne's explanation must be considered too exclusive. It has been observed in the very numerous osteotomies that have been recently done for the relief of genu valgum, that after division of the femur above the condyles the patients are usually able to move the knee freely as soon as the splint is removed, and this fact indicates, in my judgment, that the stiffness observed after accidental fracture is probably due in great part to an arthritis excited by a concomitant sprain. The stiffness of the fingers found so constantly after fracture of the radius or forearm seems to be due in part to the implication of the sheaths of the tendons in the inflammation about the injury, and it is certainly increased by the extended position. In other cases the pain is referred, when an attempt is made to flex the limb, to the seat of fracture, and thus points to implication of the fibres of the muscle in the callus or in the inflammatory thickening around it. Retraction of the peri-articular tissues and ligaments, the result of prolonged immobility, is also demonstrable in many cases.

The stiffness is, as a rule, most marked and most persistent in the aged and rheumatic; it is usually temporary, but may disappear very slowly, or last for years. Malgaigne speaks of a case of stiffness of the knee following fracture of the shaft of the femur, and persisting for twenty-one years.

Atrophy of the limb is found very frequently after fracture, and is usually slight. It is said by Gosselin[1] to be permanent and to affect not only the segment of the limb that has been fractured, but also that which is above or below. In cases where a large nerve has been injured, or where the callus is exuberant and painful, this atrophy may be very marked, and is then unquestionably due to the influence of the affected nerves; but in the common slighter cases the cause is not well understood. Gosselin's experiments and those of one of his students, Lejeune, who had also an opportunity to weigh the muscles of a man who died some time after having received a fracture of the thigh, showed that the atrophy involved the muscles themselves, and not merely the adipose tissue of the limb; each muscle when deprived of its fat weighed less than the corresponding one of the unbroken limb. Malgaigne attributed it to the prolonged compression by the retentive apparatus, but Gosselin found it equally marked in two cases of the fracture of the elbow that had been treated by continuous irrigation without bandages. He therefore rejects compression as a cause, and also the prolonged immobility invoked by others, and suggests that the atrophy is due "to a change

[1] Gazette Hebdomadaire, 1859, and Clinique Chirurgicale, 1872.

in the distribution of the nutritive materials which is a consequence of the process of consolidation. Not only does the fracture draw towards itself a greater quantity of these materials, but the callus itself, when once formed, and, after its completion, the hyperostosis require a greater proportion for their nourishment." This explanation has not been received favorably, and does not seem to be either sufficient or in accord with other allied conditions. The atrophy appears to be most marked after fractures involving, or in the immediate neighborhood of, joints. A thesis by Sabatié,[1] gives a full bibliography of the subject and discusses the different factors, but fails to make the cause apparent.

Obliteration of the large veins in the neighborhood of a fracture is thought to be a rather common occurrence, and to be the cause of the œdema which is so constantly noticed in the limb during convalescence. Its immediate cause lies sometimes in pressure upon, or injury to, the vein, by one of the fragments or splinters, and sometimes in the spread to it of the inflammation of the adjoining parts, which, by setting up phlebitis, leads to coagulation of the blood within the vessel. Gosselin has suggested also, as a possible cause of this phlebitis, the passage into the larger veins of irritating materials coming from the inflamed marrow of the bone. The œdema which results and persists until the vein becomes free, or a sufficient collateral circulation is established, is troublesome and annoying, but it is rare for any serious consequence to ensue. Nevertheless, a few cases of *fatal embolism* due to the dislodgment of the clot have been reported, and, therefore, the possibility of this accident should be noted. The first reported case, so far as I know, was by Virchow, in 1846, in Traube's *Beiträge zur experimentalen Pathologie*, fatal pulmonary embolism after extra-capsular fracture of the neck of the femur. Durodié[2] collected eight other cases, in which the death occurred twice on the 22d day, and once each on the 16th, 30th, 35th, 47th, 50th, and 57th days; one case was a fracture of the thigh, the others of the leg. Mr. Southam published in the *Lancet*, March 1st, 1879, the particulars of two cases of simple fracture of the leg in which death was caused by an embolus lodging in the pulmonary artery, as proved by post-mortem examination. In one, Pott's fracture, death took place on the 18th day, in the other, fracture of the fibula, on the 16th day.

The symptoms are the usual ones of pulmonary embolism; the patient, without any warning, suddenly grows livid, or very pale, with great dyspnœa, anxiety, and precordial distress, and dies, usually, in a few moments.

It is much more common to observe the occurrence of small emboli accompanied by more or less severe symptoms, but terminating in recovery. The symptoms are sudden dyspnœa, cough, sometimes with bloody sputa, and the physical signs of localized consolidation of the lung. The risk of this accident is sufficient to make it necessary to avoid all active movements and all rubbing of the limb when there is reason to suspect the presence of a thrombus in a large vein.

[1] De l'Atrophie Musculaire Consécutive aux Fractures. Thèse de Paris, 1878, No. 9.

[2] Etude sur les Thromboses et l'Embolie veineuse dans les Contusions et les Fractures. Thèse de Paris, 1874. No. 326, p. 55.

Fat embolism, too, is thought to be an occasional cause of death after fracture, not recognized until within the last twenty years. The fat set free by the crushing of the marrow makes its way into the veins and lymphatics and lodges mainly in the capillaries of the lungs, but also in those of other viscera, where it is easily recognized by the aid of the microscope, especially if the section is prepared by staining with osmic acid.

The first occasion on which this condition was recognized as the immediate cause of death after fracture was in 1864, and as the case fairly represents one of the clinical forms of this complication, I reproduce it from the account given by Flournoy.[1] A man was brought to the surgical clinic at Königsberg with a simple, transverse fracture of the tibia, caused by the kick of a horse. At first, all went well, but the next day he complained of great weakness, became comatose, and died 36 hours after the accident. The autopsy, made by Von Recklinghausen, showed numerous small ecchymoses in the brain, heart, skin of the shoulder, bladder, conjunctiva, and retina; hemorrhagic infiltration of the marrow of the tibia for an inch on each side of the fracture, and clotted blood between the fragments; great œdema of the lungs. The microscope revealed fat in the capillaries, small arteries, and apparently also in the veins throughout the body, but especially in the lungs, where the obstruction caused by it was so extensive that only a very few of the capillaries seemed to have remained pervious for the blood. Von Recklinghausen at once attributed the death of the patient to fat embolism, and under his inspiration Busch[2] soon afterwards published an article upon the subject which shares with one of Wagner's[3] the honor of first establishing the causal relation between fat embolism and early death after fracture.

The following three cases represent other features and illustrate the rapidity with which fatal embolism may occur and the occasional resemblance between its symptoms and those of traumatic shock.

1. A healthy man 32 years old[4] broke his right femur near the middle by a fall from a scaffold late one afternoon, and was taken at once to the hospital where a splint and ice-bag were applied. The next day he was free from pain, but in the evening his temperature had risen to 103½°, and his pulse and respiration were quickened. During the night his noisy breathing attracted the attention of the nurse, and he was found to be comatose, with deep, frequent respirations, loud, coarse râles, percussion-note clear and slightly tympanitic; pulse 100, full and strong; pupils contracted; face cyanotic; reflex irritability lost. Later a few convulsive twitchings were observed in the arms; profuse perspiration; tracheal râles. He died thirty-eight hours after the accident.

The autopsy showed the small arteries and capillaries of the lungs filled so extensively with clear liquid fat that Czerny considered it evidently the cause of death. A considerable number of similar branched

[1] L'Embolie graisseuse. Thèse de Strasbourg, 1878.
[2] Virchow's Archiv, 1866, p. 321.
[3] Archiv der Heilkunde, 1865, vol. vi. p. 481.
[4] Czerny, Berliner klinische Wochenschrift, 1875, p. 594.

fat emboli were found in the brain, corresponding usually to small ecchymoses; and some of the vessels of the kidney, especially those of the glomeruli, were filled in like manner. There was also marked œdema of the lungs.

2. A man 47 years old[1] sustained a compound fracture of the right leg and simple fracture of five ribs on the left side by the caving in of an embankment. When brought to the hospital eight hours afterwards there was emphysema of the entire anterior surface of the left side of the chest; pulse full, strong, and slow; respiration normal. Lister dressing of the compound fracture.

The next day he had no fever, and the wound was aseptic. At 9½ P. M., while feeling perfectly well, he suddenly lost consciousness; breathing slow and snoring; pulse 42, full and strong; percussion note over the chest slightly tympanitic but otherwise normal; respiration harsh. He died one and a half hours afterwards, thirty hours after the accident.

The lungs were found hyperæmic and slightly œdematous, with numerous punctiform ecchymoses under the pleura and in their substance, and very extensive plugging of their capillaries and arterioles with fat. Many of the alveoli were more or less completely filled with large, round, fatty cells, and others contained masses of red blood-corpuscles entangled in fibrin. Subperitoneal hemorrhage, liver fatty, spleen and kidneys normal except for some fat in the vessels of the glomeruli of the latter, no lesion in the brain.

3. A lad 19 years old[2] was run over by a heavy wagon and received compound fractures of the right thigh and leg, and a simple fracture of the left thigh. He lost much blood from the torn arteries of the leg, and was brought to the hospital at 4 P. M. in a condition of extreme collapse; pulse 100 and small; respirations not quickened; foot cold and insensitive. The thigh was amputated through the upper third. At 10 P. M. the breathing became rapid, without fever, and the patient died with increasing dyspnœa and tracheal râles an hour and a half after midnight. The lungs showed numerous ecchymoses scattered through their substance, with extreme fat embolism; the liver was pale; the spleen firm and full of blood; fat was found in all the glomeruli of the kidneys.

It is probable that fat embolism occurs to a greater or less extent in all fractures, for its occurrence seems to require only the bruising of the marrow, the laceration of small vessels, and the existence of a certain amount of pressure to force the liberated fat into the open capillaries or veins. All these conditions are present in fracture, and the capillaries of bone are particularly fit for this absorption because they are inclosed in bony walls which protect them from lateral pressure. It follows, therefore, and the conclusion is borne out by experiment, that fat embolism is not necessarily dangerous. So far as can be inferred from the post-mortem examinations in some cases of death by an intercurrent cause after fracture and from the results of experiment, fat

[1] Riedel, Deutsche Zeitschrift für Chirurgie, 1877, vol. viii. p. 572.
[2] Idem, p. 575.

emboli may disappear entirely from the lungs within three weeks after their formation, leaving behind them no recognizable traces of their presence and having given rise to no inflammatory lesions. The cases quoted above are all examples of death by obstruction of the pulmonary circulation within a few hours after the injury, but there are other cases in which death took place at a much later period, on the 6th, 8th, 10th, and 11th days, as the result apparently of the ecchymoses and the inflammatory processes set up in the lungs and brain by the emboli. The following case from Riedel's paper is an example:—

A man, 41 years old, of alcoholic habits, was brought to the hospital three days after he had received a comminuted fracture of the neck of the femur and the great trochanter. The following day he developed delirium tremens and jaundice, which persisted until his death two days afterwards. At the last he was somnolent, with a small rapid pulse. The autopsy showed ecchymoses in the heart under the pericardium and in the lungs under the pleura, œlema of the lungs, partial consolidation of both lower lobes, and extensive fat embolism; the glomeruli of the kidneys, and the afferent and efferent vessels completely filled with fat.

These facts, the numerous ecchymoses in many organs, and the development of localized pneumonia in the cases that survived a few days, are thought to indicate that the graver prognosis of severe fractures in the old and the alcoholic is due, in part at least, to fat embolism. Their hearts are weak, less able to force the fat through the capillaries, and their lungs, brains, and kidneys are less able to withstand the local traumatisms or the altered conditions of nutrition produced by the plugging of the vessels; and it is not without reason that some of the writers upon this subject have suggested that the dreaded "hypostatic" pneumonia may depend quite as much upon this complication as upon the decubitus which has heretofore been considered its efficient cause, and that delirium tremens or nervosum may also be a secondary effect. It is only proper to add that a recent writer upon the subject, Wiener,[1] considers fat emboli as without influence in producing secondary effects, an opinion which is shared by Dr. Peabody, the accomplished pathologist of the New York Hospital.

The symptoms in the acute and rapidly fatal forms resemble those of shock, and Czerny suggests that many deaths heretofore attributed to shock, traumatic delirium, or even contusion of the brain were really due to fat embolism. The differential diagnosis is here to be made, according to the same surgeon, by the intercurrence between the accident and the appearance of the symptoms of a period during which the patient seems to be doing well. The symptoms are varied and not very distinctive. The first one may be a sudden attack of extreme dyspnœa followed by œdema of the lungs, or a feeling of weakness without dyspnœa but with coarse râles, cyanosis, and a quick feeble pulse, or delirium, or coma. The constant signs, those upon which the diagnosis must be made, if at all, are those of disturbance of the pulmonary, and later of the general, circulation, occurring in the first day or two, and accompanied by a rapid change for the worse in the patient's condition. Exami-

[1] Wesen und Schicksal der Fett-Embolie, Leipzig, 1879.

nation of the urine, especially of that passed on the morning after the receipt of the injury, may disclose the presence in it of a few drops of fat.

The only treatment to be attempted is that directed to the vital indication, the relief of the pulmonary œdema. We are unable to remove the fat from the capillaries when it has once lodged in them, and our efforts must, therefore, be directed mainly to prevention. The broken limb must be kept quiet, in order that the laceration of the marrow and the extravasation of blood may not be increased; and as the embolism occurs promptly, amputation, whenever necessary, should be performed with the least possible delay.

There are a number of other complications, not peculiar to fractures, but occurring also after other injuries, most of which are of great gravity and make their appearance, if at all, soon after the accident. It seems appropriate to consider them briefly here, before taking up the later complications which find their sole cause in the injury to the bone. They are: extravasation of blood, including traumatic aneurism and hemorrhage, emphysema, septicæmia, gangrene, pyæmia, tetanus, and delirium.

Extravasation of blood takes place in every fracture, and even when quite extensive is usually without importance and requires no treatment. But when the blood escapes in large quantities in consequence of severe crushing of the soft parts or of the rupture of a large vein or artery it may endanger the patient's life, or render necessary the amputation of the limb.

Extravasations of exceptional size may form under the fascia, or between it and the skin. In the latter case they are commonly due to the action of a sliding force which has torn the skin away from the fascia and ruptured a large number of the small perforating veins, and, perhaps, some of the large cutaneous ones; the blood may pass along the limb to a considerable distance, discoloring the integument, or it may collect as a distinctly circumscribed fluctuating swelling, or the blood may come from deeper sources, the fracture itself, and especially the muscles torn by the displaced fragments or crushed by the original violence. In simple fractures the source of the bleeding is usually in doubt, and under such circumstances no active treatment of this symptom is necessary beyond a moderate elastic compression of the parts to prevent further extravasation and favor absorption. Serious questions associated with the symptoms may arise if the original cause of the extravasation is a severe and extensive contusion of the limb or injury to the main artery, such as the necessity for amputation, in the former, and for formal operations upon the wounded vessel in the latter.

An extravasation may, by the slowness of its absorption, prolong the period of convalescence, for the coagulation of a large quantity of blood may leave a hard clot which will provoke suppuration. In some cases it is desirable to remove the fluid blood or the serum left after coagulation by the aspirator, but this should not be done in recent cases; and if suppuration occurs, or is impending, the collection must be treated as an abscess and opened freely. Usually, before this extreme measure becomes necessary, the process of repair will have advanced sufficiently

to protect the patient from the especial dangers of a compound fracture, and the broken ends of the bones will be covered with granulations, or imbedded in a well advanced callus.

Hemorrhage from a compound fracture is often severe, and sometimes dangerous, although it is rare that a large vessel is wounded. The blood comes usually from the broken bone and lacerated muscles, and can be arrested by cold, position, and pressure, and even when a large vein has been torn the arrest of the bleeding is seldom difficult; if pressure applied methodically at the wound is not sufficient, digital pressure over the main artery of the limb will usually enable a clot to form promptly. The tourniquet should not be used, because it compresses the vein also and thereby favors infiltration of blood and increases the probability of gangrene.

Injury of a large artery is a dangerous complication. It seldom happens in an ordinary fracture, except at those points where the artery lies very close to the bone, as in the leg. The vessel may be torn across by a displaced fragment, or perforated by a splinter, or so bruised or pressed upon that its wall sloughs, or it may be opened by the extension of the suppuration accompanying necrosis. When the fracture is compound the profuseness and arterial character of the hemorrhage usually leave no doubt as to the nature of the accident, but in simple fractures it is not so easily recognized at first. The blood infiltrates the tissues of the limb and forms a distinct, fluctuating swelling, at first without pulsation or bruit, but at a later period, when a sac has formed by condensation of the parts around it, presenting one or both, a condition known as *traumatic aneurism*, *primitive false*, or *diffuse aneurism*, or *ruptured artery*, and usually to be treated according to the principles established for that lesion. It has been observed, however, that a pulsating tumor formed promptly after fracture will sometimes disappear under the moderate pressure of a simple roller bandage; two such cases were reported to the New York Surgical Society in 1879, and Cruveilhier, who had observed the fact several times, found a possible explanation in a pathological specimen which showed that the rupture of even a small artery might give rise to a collection of blood so large as to raise the suspicion of injury to the principal artery of the limb. The diagnosis may be aided by the presence or absence of pulsation in the distal branches of the artery. Verneuil[1] reported a case cured by digital pressure upon the main artery, and refers to an oral communication from Broca that several cases had been cured by non-operative measures.

Dupuytren,[2] who was the first to write upon this subject, collected six cases of rupture of an artery due to fracture, one of them associated with an external wound and frequent hemorrhages. Gurlt[3] collected twenty-five cases of aneurism and arterial hemorrhage, including Dupuytren's list; and more recently Laurent[4] has reported in full twenty-six cases of aneurism, including some of Gurlt's and rejecting others for reasons

[1] Bulletins de la Société de Chirurgie, 30th March, 1859, vol. ix. p. 402.

[2] Leçons Orales de Clinique Chirur., 2d ed., vol. ii. p. 507, 1839; being the substance of a paper read before the Acad. des Sciences, 24th April, 1825.

[3] Loc. cit., vol. i. p. 526.

[4] Des Anévrysmes compliquant les Fractures. Thèse de Paris, 1874.

which do not appear. Of these, 16 followed fracture of the leg, 5 of the arm, 2 of the thigh, and 1 each of the forearm, carpus, and a rib. Of Gurlt's 25 cases 4 were in the thigh, 20 in the leg, and 1 in the forearm; 11 were "false traumatic aneurisms," 3 after fracture of the thigh, 8 of the leg; and 14 were cases of arterial hemorrhage, most of them accompanied by extensive infiltration, and 1 of them (leg) followed by the formation of an aneurism. Nepveu[1] collected 53 cases of injury to the vessels in fracture of the leg, which he classifies as follows:—

Primary accidents, 20 cases.	External hemorrhage	14
	Collection of blood	2
	Infiltration of blood	1
	Immediate diffuse aneurism	3
Secondary accidents, 30 cases.	Consecutive false aneurism	11
	Secondary hemorrhage	15
	Gangrene	3

The statistics of the treatment employed would be valueless without the details of the cases, for in most of them it was based upon principles that have now been abandoned or greatly modified. Mr. Holmes[2] refers to "the decided tendency to recovery manifested by wounds of healthy arteries when uncomplicated by external injury," and adds: "It seems abundantly clear, therefore, that surgical interference in these cases can only be justified by the presence of alarming symptoms; and that by the aid of simple position, and, perhaps, in appropriate cases light and even compression, a great number of arteries wounded in fracture will heal." If an aneurism forms promptly after a simple fracture, it should be treated by ligation or compression of the main artery above; if it forms slowly and is not cured by pressure, it may be proper to wait until consolidation of the fracture is well advanced, as also when it is formed at a late period by ulceration of the artery, and then to lay it open and tie the vessel above and below the opening in it; this failing, the trunk of the artery must be tied above, or the limb amputated. Agnew[3] says amputation is imperative in compound fractures of the thigh complicated by laceration of the femoral artery, and in similar injuries of the leg in which both tibial arteries are torn.

Emphysema.—The emphysema which consists in the infiltration of atmospheric air through the meshes of the subcutaneous tissue is observed most commonly after fracture of the ribs complicated by wound of the lung, and after fracture of the bones of the face communicating with the air-passages, but also occasionally, and to a very limited degree, about the wound of a recent compound fracture of a limb. In the first case, it is due to the escape of the inspired air through the wound of the lung, and its passage, into the wall of the chest under the influence of the movements of expiration through the gap created by the fracture. It is seldom of any importance, although cases are mentioned in which it has spread over most of the surface of the body. If necessary, the

[1] Bull. de la Société de Chirurgie, 1875, p. 365.
[2] Syst. of Surgery, Am. ed., vol. ii. p. 384.
[3] The Princip. and Pract. of Surgery, vol. i. p. 742, 1878.

air may be let out through a trocar introduced through the skin at one or more points, but it usually undergoes prompt spontaneous absorption.

The other variety, the emphysema found about a recent wound with or without fracture, raises much more serious questions. First described by Velpeau, it was attributed by him to the sucking in of the air through the wound by the contraction of the muscles, or the movements of the segments of the broken limb. It is unquestionable that this may sometimes be its origin, but it is equally certain that it is much more often due to commencing gangrene or acute septicæmia, and the importance of the first is as nothing in comparison with the extreme gravity of the second, unless it may possibly be regarded as one of the latter, by serving to introduce germs capable of exciting putrefaction. The air that passes through the lungs into the tissues of the chest-wall is filtered of all organic matter in its course through the air-passages, and is thereby rendered incapable of producing this effect. As the emphysema of gangrene is only a symptom of that complication, and as the process can originate without the aid of an external wound, it will be more properly spoken of in that connection in the following section.

Gangrenous Septicæmia. (Bronzed erysipelas; acute purulent œdema; grave spontaneous emphysema.)—This diversity in the names given by different authors to this extremely dangerous complication, not of fractures only, but also of many other wounds, is due, not to a corresponding variety in its symptoms and course, but to different views of its nature, or of the importance attributed to different symptoms. I prefer the term *gangrenous septicæmia*, because it expresses both the general and local conditions, the acute constitutional poisoning which kills the patient, and the local change which accompanies and, perhaps, causes it. The name *bronzed erysipelas* given by Velpeau graphically indicates the symptoms presented by the skin, but involves a questionable etiology; *acute purulent œdema* and *grave emphysema* express only a single symptom each, the former that of the serous or sero-purulent infiltration of the tissues, the latter that of the putrefaction of the same liquid.

The complication is especially common in wounds accompanied by much contusion or laceration of the surrounding parts, but may occur even when there is no external wound. It begins promptly after the accident, usually within a few hours, always within a few days, with a swelling about the wound and a change in the color of the corresponding skin to a dark hue at the points nearest the wound, and a brown or brownish-yellow one at the outer border, or over the greater portion of the swelling if the latter advances rapidly. The fingers pressed lightly upon the surface recognize a fine crepitation due to the presence of gas beneath, and the wound, if there be one, discharges a thin, reddish-brown liquid of an extremely fetid odor, and containing a few bubbles of the same gas, and sometimes pus. If suppuration has fairly begun before the occurrence of the complication the flow of pus diminishes, giving place more or less completely to the thin liquid mentioned. The skin adjoining the wound soon becomes black and gangrenous, and this gangrene extends rapidly or may even appear at distant, isolated points. The temperature rises, sometimes with a chill, and the pulse quickens;

the patient is conscious, but dull and with an anxious expression, at first, and soon becomes unconscious or delirious; the face is drawn, the eyes haggard, the skin and conjunctiva yellow, and death usually occurs on the second or third day, with all the symptoms of an overwhelming constitutional poisoning. If incisions are made in the affected skin they give issue to a serum similar to that furnished by the wound, and, if carried through the deep fascia, the muscles protrude through them in consequence of the tension to which they are subjected.

The cause of this most grave affection is not entirely understood, but its occurrence is certainly favored by the coexistence of an open wound in contact with the air, a fact which points to the introduction of the poison from without. It is favored also by crushing of the soft parts and injury to the nerves, and as it occasionally develops when there is no external wound, it seems possible that its cause may sometimes lie in altered conditions of nutrition or vitality.

The common association with an external wound and the success of the antiseptic method in the treatment of wounds in general impose upon surgeons the obligation to employ this method rigorously in all cases in which this complication seems at all likely to ensue, for it is only by prevention that we can hope to be of service to the patient. When the disease has appeared there is but little chance of saving the limb, or even the life. Incisions into the affected parts are worse than useless unless they can be combined with the permanent antiseptic bath, for the limb is saturated with the liquid, and it is fruitless to try to drain it away, and the incisions only furnish additional opportunities for the entrance of the poison into the system. Immediate amputation well above the affected region offers the only chance, and that but a slender one, of saving the patient's life.

Gangrene.—Excluding the form just described and limiting our attention to those due to mechanical causes acting directly upon the tissues that become gangrenous, or indirectly through the arteries and veins which carry on their blood-supply, we have to consider local gangrene limited, at least at first, to the region of the fracture, and total gangrene of a larger or smaller segment of the limb. The former is produced in fractures by direct violence by the simultaneous crushing of the skin and the tissues lying between it and the bone; in fractures by indirect violence it may be produced by the pressure from within outwards of an unreduced fragment, or by the compression of the skin between such a fragment and the dressings. The latter form is due to the partial or complete arrest of the circulation through the principal arteries and veins of the limb by changes effected in them by the original causative violence (rupture, bruising, perforation), or by their compression against the edge of a projecting fragment or under an improperly applied splint. The gangrene may be moist or dry; the latter is due to deficient afflux of blood coinciding with a free return circulation, is less likely to spread, and is less dangerous to the life of the patient; the former is the more common, is frequently associated with obstruction of the venous current, and is more likely than the other to spread and give rise to septic poisoning.

As this complication leads not infrequently to suits for malpractice, it

is important to know that it is often due to causes beyond the control of the surgeon, such as the associated contusion, the pressure of extravasated blood, injury of the main vessels or nerves, and the occlusion of an artery by the pressure of an irreducible fragment. The following two cases will serve as illustrations of the last two causes. Many similar ones have been recorded.

1. The wheel of a heavily laden wagon passed across the middle of the patient's arm, fracturing the humerus, but leaving no notable external traces. The radial pulse could be felt the next day, and the hand could be moved. On the following day sensibility, functions, and circulation had ceased in the forearm. The limb was amputated above the fracture, and its examination showed the brachial artery filled by a firm clot at the point corresponding to the passage of the wheel, and for a distance equal to its breadth.[1]

2. A lad, seventeen years old, had his femur broken just above the knee by the fall of a bale of goods. On the fifth day "the whole foot and leg to within three inches of the knee were in a state of complete mortification, the parts being tumid, crepitous when pressed, covered with dark vesications, cold, and completely insensible." The limb was immediately amputated just above the fracture, and its dissection showed a perfectly transverse fracture two and a half inches above the lower end of the femur, with the upper fragment dislocated behind the lower one, and overriding it three-quarters of an inch. The femoral artery and vein were "thrust backward, and tensely drawn across the sharp posterior margin of the superior fragment in such a manner that it was perfectly obvious that the circulation in both vessels must have been completely interrupted."[2]

The young, women, and the old are more exposed to gangrene than adult males, and therefore splints and bandages must be used upon them with caution, and their effects closely watched. In the old, gangrene is more likely to be the result of a contusion than of pressure alone, for their atheromatous arteries are easily injured and torn.

The symptoms vary with the extent and character of the morbid process. Localized gangrene caused by the pressure of an unreduced fragment may present no symptoms beyond the change in the portion of skin involved, and a slight rise of temperature coinciding with the establishment of suppuration and of a communication between the seat of fracture and the air; and gangrene due to arterial obstruction may be dry in character, and marked only by the shriveling and blackening of the distal portion of the limb. But it is much more common to meet with symptoms resembling those of the second case mentioned above; the limb becomes swollen, dark, insensitive, and cold; bullæ containing a dark-colored serum appear on the surface, and the edge of the discoloration is marked by an inflammatory zone, which may in turn become gangrenous, or may suppurate and form the so-called line of demarcation. The effect upon the patient's general condition presents all the grada-

[1] Stromeyer, Maximen der Kreigsheilkunst, 1855, p. 92. Quoted by Gurlt, loc. cit., i. p. 563.

[2] N. R. Smith, Am. Journ. Med. Sciences, 1838, vol. xxiii. p. 66.

tions between a slight one and a very severe one resembling that of gangrenous septicæmia.

The treatment, in like manner, varies with the severity of the affection. In the circumscribed cases local measures, intended to hasten the separation of the slough and to control its putrefaction, are sufficient; when an entire segment of the limb is involved and the process tends to self-limitation, to the formation of a line of demarcation, it is well to wait until the latter is clearly defined and then to amputate; but when the gangrene is spreading, and a general infection threatens, recourse must be had to immediate amputation above the seat of injury. Delay, even for a few hours, is dangerous, and the surgeon must have the courage to urge the immediate sacrifice of the doomed limb as the only means of saving the imperiled life.

Suppuration (simple or phlegmonous); *Pyæmia; Necrosis.*—Suppuration about a simple fracture is rare, except when due to contusion of the overlying soft parts, or to the pressure of a projecting fragment. I have met with no instance of it, except after fractures involving joints,[1] but it is spoken of by most writers as a possible complication of fracture in weakly patients. The abscess formed by it leads necessarily to the transformation of the fracture into a compound one, either by its spontaneous opening or by the intervention of the surgeon.

Acute osteo-myelitis after simple fracture is so rare that it is not usually mentioned in the text-books. Spillmann[2] reports a noteworthy case that occurred in his own practice. The patient had received a fracture of the lower third of the leg, not communicating with the joint, by a fall from a height of five feet. When first seen, thirty-six hours after the accident, the limb was enormously swollen, very painful, and fluctuating. Incisions carried through the skin and fascia gave exit to a large quantity of pus mixed with drops of fat. The patient died during the following night.

In a case of separation of the upper epiphysis of the humerus quoted above (page 52) from Esmarch, suppuration followed, apparently in consequence of an error in diagnosis which led to two attempts to reduce a supposed dislocation.

Suppuration about a compound fracture, in which primary union of the divided soft parts has not been obtained, is almost invariably associated with more or less burrowing of the pus, sometimes with grave phlegmonous inflammation of the limb, and occasionally with pyæmia or necrosis. These grave accidents, which were frequent and fatal for-

[1] Unless the following case is one: A lad, nine years old, was brought to me with the history that nine weeks previously he had fallen heavily upon the left side of his chest while skating. No symptoms were noticed at first: on the third day a hard lump formed at the seat of the blow, on the seventh rib a little external to the mammary line, and he became feverish and delirious. He was treated first with poultices, then with cold, and again with poultices. In six weeks the lump, which had been hard, but not very painful or red, opened and discharged pus. The probe touched bare bone. I made an incision and removed three necrosed irregular portions of bone, one of them being one and a quarter inches long, and having the breadth and thickness of the rib. The patient showed no signs of constitutional vice, and the history of the case points to suppuration originating, not in a contusion of the soft parts, but in the fracture itself.

[2] Dict. Encyclopédique des Sciences Méd., 4th series, vol. iv. p. 156.

merly, have become rare under antiseptic treatment, and even in hospitals where ten years ago more than one-fourth of the compound fractures terminated fatally by pyæmia, this complication is now entirely absent for months together. This relative immunity is due to the prevention of putrefaction and to the thorough drainage of the wound which now forms so important a feature of treatment.

The symptoms of unhealthy or excessive inflammation after compound fracture are in general terms as follows: At an earlier or later period after the receipt of the injury, usually within the first few days, the edges of the wound become swollen, the adjoining skin tense and red, the discharge, perhaps, fetid, the patient feverish and uneasy. The conditions are aggravated during the following days, the swelling and redness extend up the limb, and the surgeon finds points of greater tenderness and hardness, pressure upon which causes pus to flow from the wound; a chill occurs, and the temperature rises to 103° or 104°, the tongue becomes dry, the patient is unable to sleep without an opiate, and is slightly delirious at times; the temperature falls in the morning and rises in the afternoon, with a regularity that is one of the characteristics of hectic fever; chills occurring at intervals announce the formation of metastatic abscesses in the viscera or joints; pyæmia is established, and the patient dies exhausted in a few days or weeks. Meanwhile the work of repair seems to be arrested at the wound; the discharge is profuse, thin, reddish, and offensive, and the bone may be seen lying white and bare at the bottom of the cavity.

The treatment will be given in detail in the following chapter. It is addressed to the purification and drainage of the wound by the free use of antiseptics and by counter-openings at dependent points, to the evacuation of adjoining abscesses, to the control of the inflammation by poultices, cold, hot water, irrigation, or baths, and the support of the patient's strength by food, stimulants, and medicine.

Necrosis of splinters has been spoken of in the chapter on repair. Necrosis of a portion of one of the principal fragments may occur in a compound fracture as the result of the stripping off of the periosteum, and of the destruction of the corresponding portion of the marrow by crushing or sloughing. The compact tissue being thus deprived of its blood-supply by the rupture of the vessels which come to it from the periosteum and the destruction of those coming from the marrow, dies, and is slowly separated from the portion that remains alive by the formation of a line of demarcation at their junction, as shown in fig. 75. The dead piece may lie loose in the cavity of the wound, or may be enveloped more or less completely by the callus, which is continuous with the lining portion of the shaft through new bone formed on the under side of the loosened periosteum (fig. 76). A few cases are on record in which a long piece, 6½ and 7 inches in two cases, comprising the entire thickness of the shaft, had died and been removed after some weeks by the surgeon.

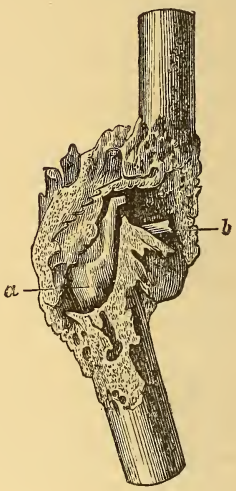
The small pieces of bone which are so frequently cast off during the healing of a compound fracture are composed sometimes of splinters and sometimes of portions of the callus which have died in consequence of the excessive activity of the productive osteitis. The continued deposi-

tion of bone narrows the canaliculi until they become no longer pervious, and the part dies through lack of blood. It is an irregular and objectionable manifestation of the effort made by nature to remove an excessive and unnecessary amount of tissue.

Fig. 75.

Necrosis of the end of a long fragment after prolonged suppuration.

Fig. 76.



Necrosis after fracture of the shaft of the femur, with enveloping callus. *a*. The sequestrum. (Gurlt.)

The presence of a necrosed fragment is shown by the persistence of a sinus, at the bottom of which a bare and sometimes movable piece of bone can be felt with the probe. The treatment consists in the enlargement of the opening by the knife or compressed sponge, and the removal of the fragment. If necessary, the involucrum or the obstructing portion of the callus must be cut away. Sometimes the wound closes and the fragment makes its presence known only after the lapse of months or years.

Muscular Twitchings and Tetanus.—Involuntary twitchings of the muscles of the injured limb are not uncommon in the first week following the injury. They are most likely to occur at night, just as the patient falls asleep, and cause pain by the movements they communicate to the broken bones. Sometimes the pain is not so disturbing to the patient as the feeling of indefinite dread which may accompany the twitchings, and in this respect, as in others, they resemble the similar phenomena observed after amputations and excisions. They are relieved or prevented by solid support of the limb, reduction of displacement, and a well-adjusted splint or immovable dressing. They rarely continue beyond the first week, but in a few cases have merged gradually into tetanus.

Tetanus is not a common complication of fracture. Poland[1] found that in thirty-two years, 1825 to 1857, at Guy's Hospital it had occurred sixteen times after compound and once after simple fracture, and it is worthy of note that seven of these cases were lacerations and fractures of the fingers or hands, and one of the toes. The statistics of Lawrie and Peat quoted by Gurlt (loc. cit., p. 554) give four cases after simple fracture and seven after compound; while of twenty reported cases collected by Poland and analyzed by Gurlt, one was after simple and nineteen after compound fracture, and in seven others there was simple fracture associated with lacerated wounds.

Some autopsies have indicated as a probable cause injury to, or pressure upon, a large nerve by one of the fragments; in other cases the cause appears to be the same as in wounds that are not associated with fracture. Poland calls attention to the fact that in a number of cases the exposure of the patient to a sudden change of temperature seemed to have been the immediate exciting cause.

Treatment holds out but a slight prospect of success. If it is known or suspected that a fragment is pressing on a nerve the pressure must be relieved. Other measures are those recommended when the affection complicates other wounds, and for them the reader is referred to works on General Surgery. Occasional successes have been obtained by the administration of chloral in large doses, Calabar bean, the inhalation of chloroform, and the division or stretching of the nerve supplying the region of the wound. Gurlt recommends prolonged diaphoresis, maintained by hot air or vapor, in cases where chilling appears to have been the cause.

Delirium Tremens and Nervous Delirium.—Nervous delirium, or traumatic delirium, as it was at first called by Dupuytren, who was the first to describe it, resembles delirium tremens so closely that the diagnosis between them is not always easy to make. It presents all the symptoms of delirium tremens except the tremor of the limbs. There is the same sleeplessness, fixed delusion, loss of appetite, and insensibility to pain. Both occur after slight as well as after severe injuries, and as delirium tremens attacks habitual drinkers who are not drunkards as well as those who drink to excess, the differential diagnosis cannot always be guided by the scanty information obtainable concerning the patient's habits. Fortunately this is not of much practical importance, for the treatment is the same.

Usually one or two sleepless nights give warning of an approaching attack, and if this warning is heeded, if sleep is secured by morphine or chloral, the bowels moved by a brisk purge, and the strength supported by a nutritious and easily digestible diet, the attack may be averted or its severity diminished. When the disease has fairly set in it must be treated according to the method that commends itself to the choice of the surgeon. These methods are numerous and differ widely; the reader is referred to formal articles upon the subject. It may be said, however, that the indications are to procure sleep, to support the strength,

[1] Guy's Hospital Reports, 1857, p. 1.

and especially to avoid excitement and muscular action. The patient should be controlled not by mechanical means, such as a strait jacket or tying him in bed, but by the will and tact of an attendant. Holmes and Bryant both recommend morphine to be given subcutaneously in half-grain doses, a diet of beef-tea, milk, and eggs, and the avoidance of stimulants.

The remote consequences or complications remaining to be considered are *exuberant and painful callus*, *paralysis by injury to or inclusion of a nerve* and *secondary fracture*. Failure of union and vicious union will be considered in separate chapters.

Exuberant and Painful Callus.—Excessive size of the callus, common in the earlier stages of repair and sometimes persistent, does not require surgical attention unless it interferes with the functions or nutrition of the limb, or is due to the presence of a sequestrum or splinter or to disease of the callus itself. A different opinion was held by the earlier surgeons who sought to remedy it by diet, astringent applications to the surface, and compression, and, these failing, by excision of a portion. According to Malgaigne, it is found most frequently after fracture of the femur below the trochanters, and is then probably due to unreduced displacement of the fragments. A sudden increase in size, accompanied by angular or longitudinal displacement, has been observed not infrequently after premature use of the limb. One of the best known cases is that of Weinhold of Halle, quoted by Malgaigne and most subsequent writers.

The patient, a lad of 18 years, began to walk four weeks after he had fractured his thigh in the middle third. Six weeks later the limb presented a shortening of two inches, and the callus had become enormous, measuring eighteen and a half inches in circumference; the surrounding tissue was engorged, and there were fistulous abscesses at various points. Extension with pulleys failing to reduce the displacement, Weinhold drilled into the callus an inch on the outer side of the femoral artery with the intention of passing a seton so as to soften it. He encountered in its centre a cavity four inches in diameter, passed the drill through and out upon the other side, and followed it with the seton. Free suppuration ensued and led by the fifth week to the resolution of the engorgement of the soft parts and the closing of the fistulæ; the callus softened until it yielded under the pressure of the finger, and then Weinhold renewed the extension with such success that by the tenth week there remained a shortening of only two lines. The seton was retained a fortnight longer, and a few weeks later the patient was able to walk without crutches, the thigh had regained its natural size, and the wounds had closed.

In other cases, especially after gunshot fracture, the excessive formation of callus is due to the presence of a splinter or sequestrum. These cases are usually marked by persistent suppuration, but it sometimes happens that the fistula closes and the patient remains apparently well for months, and even years, until, without known cause, or under the influence of fatigue, traumatism, or chilling, the part becomes painful and swollen, and an abscess forms. A number of such cases are contained in a thesis

by Tisserand,[1] of which I reproduce the following, one of splinter, the other of necrosis.

Richet was called, in 1863, to see a gentleman who, seven years before, had broken his leg. The fracture had united after some delay, and the patient had resumed his usual occupations. Without known cause other than fatigue, the limb had suddenly become extremely painful and much swollen at the seat of the old fracture. Richet thought he found deep fluctuation, and made a free incision down to the bone, but without encountering pus; he then forced a director into the bone, which proved to be a mere shell, and a gush of thick pus followed. He found within the cavity and removed a smooth splinter as large as the little finger. The wound healed promptly, and the patient had remained well up to the time of the last report, sixteen years afterwards.

In 1868 the same surgeon treated a compound fracture of the leg; at the end of four months consolidation appeared to be perfect. Eighteen months afterwards an abscess formed at the seat of fracture, bare bone was felt, and Richet cut down upon and removed the necrosed but still adherent end of one of the fragments. The patient made a complete recovery.

In a few cases an abscess has formed within the bone at the seat of fracture and presented the symptoms and appearances characteristic of the central abscesses which are found in or near the expanded ends of the long bones, especially the tibia, during or just after adolescence, and without containing any sequestrum. One such case was reported by Desprès;[2] a man of 26, with an abscess within the tibia at the junction of the upper and middle thirds nine years after a fracture of the same bone just above the ankle. Pain had been felt about once every six months since fracture, and had been persistent for the five months preceding his admission to the hospital. The case is not so demonstrative as I should like, for the abscess was too far removed from the seat of the fracture, and the patient's age was such that its formation may have been only a coincidence. More positive cases are contained in a thesis on abscesses in bone, published in Paris, if my memory serves me, by Ed. Cruveilhier, about 1863, but unfortunately I am unable to verify my recollection. The diagnosis in this class of cases is made by attention to the recurrence of pain and swelling at the same point; the treatment is to evacuate the abscess by applying a trephine at the point where the maximum of pain on pressure is found.

In addition to the cases in which the pain is certainly due to an inflammatory process there are others in which pain, sometimes so severe as to lead to amputation, accompanies and follows regular repair without recognizable cause, and certainly not due to inflammation of the callus or bone. In some cases it has been caused by injury to, or pressure upon, a nerve by the edge of a fragment or the callus, and in still others it has been attributed to the strangulation of a nerve within the callus. This complication has been made the subject of an excellent thesis by Pasturaud,[3] and has been studied especially by Gosselin in his *Clinique Chi-*

[1] Des Abcès intra-osseux consécutifs aux Fractures. Thèse de Paris, 1879, No. 524.
[2] Bulletins de la Société de Chirurgie, 1877, p. 584.
[3] Etude sur les Cals douloureux. Thèse de Paris, 1875, No. 70.

rurgicale de la Charité, and the article *Ostéite* of the *Nouveau Dictionnaire de Médecine et Chirurgie Pratiques*. The latter author attributes the pain in the earlier periods to a non-suppurative osteitis within the callus, and in the later stages to an *osteo-neuralgia*, of which, however, he says he can give no explanation. Pasturaud explains it by the supposition of injury to nerve filaments or nerve trunks at the time of the accident, an injury which results in a progressive neuritis similar to that observed occasionally after injuries of the soft parts alone. He supports his argument by a few clinical facts and by copious quotations from Dr. Weir Mitchell's valuable work on Injuries of the Nerves.

The pain is usually severe, almost continuous, and increased at night. In a case of fracture of the leg reported by Nicod, in 1818, the suffering increased so steadily as consolidation advanced that the patient died exhausted by it. In other cases it is intermittent, recurring after slight shocks, or movements, or even spontaneously, or after a change in the weather. Motor or sensory changes, paresis, hyperæsthesia, or anæsthesia in the limb below the fracture indicate division of and injury to a large nerve, as in the cases quoted below in this and the two following sections. Local alterations of nutrition are produced by the same cause, and may appear as ulcerations of the skin, atrophy of the limb, or, more commonly, as delay in consolidation.

In the cases of pure neuralgia, that is, of pain without motor or sensory changes, the treatment is that of other neuralgias, and in some of the reported cases a complete cure has been effected by repeated blistering. In one case (Dr. Hayes Agnew, quoted by Dr. Weir Mitchell, loc. cit., p. 295) it was considered necessary to excise two and a half inches of the ulnar nerve just above the elbow; the recovery of motion was almost perfect, and of sensation very great. In another, of intense neuralgia following a blow upon the region of the epitrochlea, Denucé[1] cut down upon the ulnar nerve, found it pressed upon by the displaced epitrochlea, excised the projecting part of the bone, and cured the patient.

In the cases in which the associated symptoms point to inclusion of a large nerve in the callus, or its irritation by the bone or callus, an operation may be undertaken for the removal of the cause. Such operations have been successful in some cases and have failed in others. Thus, Prof. Trélat[2] was called to treat a child eight years old, who had received a fracture of the humerus in the lower third, which had united with much overriding of the fragments and an exuberant callus. There was paralysis of the extensor muscles of the forearm, a point of extreme tenderness on pressure corresponding to the outer and lower edge of the upper fragment, and hyperæsthesia of the outer surface of the forearm. After a long and careful search Trélat found the cutaneous branch of the musculo-spiral nerve imbedded in dense cellular tissue and resting upon the edge of the upper fragment. It had at this point the appearance of a ganglion, or rather of a plexus of nerves, tightly bound together by fibrous tissue; he dissected it free and excised the projecting part of the bone. The operation relieved the pain, but the paralysis persisted;

[1] Dict. de Médecine et Chirurgie Pratiques, art. Conde, p. 721.
[2] Pasturaud, loc. cit., p. 49.

electricity was used until the date of the report a year later, and at that time the patient had not entirely regained the use of the wrist.

In a case[1] of fracture of the forearm, in which the median nerve was pressed upon by the lower fragment, Prof. Hamilton excised the prominent portion of the bone, but without success. A year after the operation the muscles of the hand and forearm were completely paralyzed, and from time to time very painful.

An exuberant callus, especially if associated with displacement of the fragments, may give trouble by pressure upon nerves and bloodvessels, which will require an operation for its relief. Delens[2] reports a case in which an exuberant callus after fracture of the clavicle caused complete disability of the arm by pressure upon the brachial plexus and subclavian artery. It was entirely relieved by resection. He refers to a case in which Vogt resected the upper end of the humerus, after fracture at the surgical neck with pseudarthrosis and exuberant callus, to relieve loss of power and sensation due to pressure upon the nerves.

Paralysis due to Injury of a Nerve.—Division, laceration, or contusion of a large nerve by the broken bone, at the moment of the fracture, is not a common complication, but still it has been observed in connection with fractures of all the principal bones of the limbs, the clavicle, and the pelvis. It is most common in the arm after fracture of the humerus in its middle third, or of the internal condyle, the musculo-spiral being involved in the former case, the ulnar in the latter. A number of interesting cases are given briefly by Dr. Weir Mitchell,[3] together with references to the principal papers on the subject, the most complete of which are those by Ferréol-Reuillet[4] and Callender.[5]

In a case reported by Berger,[6] occurring in the service of Prof. Gosselin, the nature of the lesion was verified by autopsy. The fracture was at the surgical neck of the right humerus, and the symptoms were paralysis of the muscles supplied by the musculo-spiral nerve, anæsthesia of the back of the arm, back, and outer side of the forearm, of the outer two-thirds of the hand, and of the first three fingers. The patient died of intercurrent scarlet fever, and the autopsy showed the lower fragment displaced upwards and inwards, and the musculo-spiral nerve stretched across its edge. The nerve was reduced two-thirds in size for the distance of an inch, and showed a great excess of fibrous tissue with destruction of the nerve-tubes.

The only case of this class, exclusive of gunshot fractures, which came under Dr. Mitchell's observation, was one in which the sciatic nerve was bruised at its point of emergence from the sciatic notch by a fracture of the pelvis, occasioned by a fall from a height of forty feet. Intense neuralgia followed and was relieved by blistering. The patient made a complete recovery.

The symptoms, course, and result vary with the function of the nerve

[1] Quoted by Pasturaud, p. 47.
[2] Archives générales de Médecine, Aug. 1881, p. 170.
[3] Injuries of Nerves, p. 104.
[4] Etude sur les Paralysies du membre supérieur liées aux Fractures de l'Humerus, Paris, 1869.
[5] St. Bartholomew's Hospital Reports, vol. vi. 1870.
[6] Bulletins de la Société Anatomique, Juillet, 1871.

and the degree of the injury. Except after complete division, or when the pressure upon the nerve is permanent, recovery under appropriate treatment (for which the reader must be referred to special works) appears to be the rule.

Paralysis by Inclusion of a Nerve in the Callus.—A few cases have been reported in which paralysis of one or more groups of muscles has been caused by the pressure of the callus upon a main nerve-trunk included within it. This accident happens only when the nerve lies close to the bone at or near the point of fracture, as in the case of the musculo-spiral nerve in fractures of the shaft of the humerus. The symptoms are loss of power and of sensibility, if the nerve is a mixed one, noticed usually on the removal of the dressings towards the end of the period of repair. Electrical stimulation of the nerve above the callus produces no effect upon the muscles, and the latter lose also their power of reaction to electrical currents applied directly to them. The lesion lies in the compression of the nerve by a fragment or by the continuous deposit of bone around it. It lies in a groove or tube, the calibre of which steadily diminishes by progressive deposit of bone upon its surface, just as the vascular canals of new or inflamed bone diminish in productive or condensing osteitis; but as all attempts made to produce this condition experimentally have failed, we must believe that the tendency to this filling up of the channel or tube in which the nerve lies is slight. Probably an associated neuritis is required to effect the result, one due, not to the strangulation of the nerve, but to antecedent bruising. The treatment consists in the liberation of the nerve and its subsequent stimulation by the interrupted or, better, the constant current. The following case illustrates the prominent features, and is the first in which an operation was done to relieve the disability.

L,[1] 22 years old, received a compound fracture of the right humerus at the junction of the lower two-fifths and the upper three-fifths, with projection of the lower fragment. The limb was placed in a starch apparatus and kept there for forty days. During the first few days the patient complained of sharp lancinating pain at the seat of the fracture. On removal of the apparatus complete paralysis of the extensor muscles of the hand was discovered.

Four months after the accident he consulted Ollier, who found the bone firmly united with a slight increase in its size at the seat of fracture, and with inequalities behind that were easily recognizable by the finger. The forearm was atrophied, and there was complete paralysis of the extensors and of all the muscles of the forearm supplied by the musculo-spinal nerve. No electrical reaction in these muscles, notable diminution of sensibility in the thumb and forefinger. Pressure over the course of the nerve just below the callus caused vague sensations in the posterior portion of the forearm.

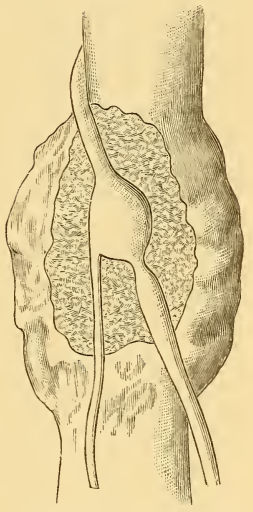
After using electricity for two months without any gain M. Ollier made an incision three inches long in the course of the nerve at the level of the callus, and on dissection found a branch of the nerve which he traced back into the callus. He then cut off a portion of the callus care-

[1] Ollier, Traité de la Régénération des Os, vol. ii. p. 414.

fully with a chisel and exposed a closed canal in it in which was found the nerve; the canal was then laid open upwards and downwards for a distance of two inches, and the nerve liberated. It was compressed at one point to a diameter of $\frac{1}{8}$th inch by a spicula of bone, apparently a portion of the lower fragment, and enlarged above it to a diameter of nearly half an inch; below the compressed part the size was normal. The spicula was cut away, the nerve loosened from the underlying bone, the adjoining periosteum removed, and the wound closed. The paralysis of sensation and motion gradually disappeared, and the patient was completely cured.

In another case reported by Delens,[1] the same paralysis was observed after fracture of the humerus in the lower third, a few days after the removal of a plaster splint which had been applied immediately after the accident and kept on for forty days. At the operation the nerve was found lodged in a bony groove of new formation, flattened, and incrusted with spiculæ, also of new formation. It was liberated, and the wound closed. Within a week the power of voluntary motion had been partly recovered, but afterwards, under the influence of a diffuse phlegmon of the other arm originating in a vaccination pustule, it was again lost, and was only regained imperfectly.

Fig. 77.



Ollier's case of inclusion of the musculo-spiral nerve in the callus.

Secondary Fracture.—It occasonally happens that after a fracture has united and the patient has begun to use the limb again, or has even used it for some time, the callus or the bone breaks again at the same point. It has been shown that the callus is composed of a more or less bulky mass of spongy bone, which requires considerable time to acquire its full strength and to become firmly united with the principal fragments. During its evolution, therefore, it is liable to be broken or separated from the fragments by the action of any such force as may cause a fracture in a normal bone, and the shorter the period that has elapsed since the original accident the greater is this liability. Furthermore, if the fragments are so displaced that they give each other but little support and the strength of the union depends solely upon the solidity of the callus, this liability to fracture is still further increased. Consequently, we find secondary fracture occurs in the great majority of cases soon after the splints have been removed and the patient begins to use his limb, and especially after fractures of the shaft of long bones that have united with much displacement. It is rare, if not unknown, after fracture of the short spongy bones or of the expanded extremities of the long ones. It may be complete or incomplete, resembling in the latter case the infraction or bending described in Chapter II. It is produced by the same causes as an ordinary frac-

[1] Bulletins de la Société de Chirurgie, 1880, p. 262.

ture, by muscular action, or even, in the lower extremity, the weight of the body in walking.

Experiments were made by Jacquemin[1] to determine the amount of force necessary to produce a secondary fracture. He took the femur of a man who died of pneumonia forty-five days after its fracture, cleaned it, and fixed it upon a table with the callus and long fragment projecting beyond the edge, and attached weights to the projecting end. 62 pounds caused the callus to bend without apparent rupture; 66 pounds caused complete separation, the callus remaining attached to the upper fragment. An oblique fracture of the humerus treated in the same manner after death on the fifty-ninth day bent and broke under a weight of less than 62 pounds.

The periods at which secondary fracture has been observed vary from a few days or weeks to several years; in the latter cases the violence that produces it is usually such as would be thought sufficient to cause fracture of the bone in its normal state. In exceptional cases repeated fracture occurs after slight causes, and is then to be attributed to defective formation of the callus. In 37 cases analyzed by Gurlt, it occurred 20 times in the femur, 11 times in the leg, 3 times in the forearm, twice in the arm, and once in the clavicle; in 2 (femur and leg) it occurred twice, and in 1 (femur) three times. In 3 cases the secondary fracture was incomplete (infraction), at intervals of 13 weeks, 133 days, and about 6 months; the patients being 19, 16, and 13 years of age respectively.

The symptoms are the usual ones of fracture: mobility and crepitation; or, in the case of infraction, deformity by the production of an angle at the point of fracture. The treatment is the same as for an ordinary fracture: reduction and contention for the complete; reduction, rapid or gradual, and contention for the incomplete. Advantage, whenever it is necessary and possible, must be taken of the accident, to overcome any previous displacement that may have favored the production of the second fracture. In fractures that recur more than once, shortening, often to a considerable extent, is to be expected. Gosselin[2] reports a case of a man of 25, who broke his femur six times in the course of twenty months. The fractures did not occur when he began to walk, but from the eighth to the fifteenth day thereafter, and generally in consequence of a slight effort, either to save himself from falling or to run, and once while dancing. Each time the patient had been allowed to get up on the forty-fifth day. Gosselin saw him after the last fracture, kept an apparatus on for two months, and the patient in bed for three months. There was permanent shortening of $2\frac{1}{4}$ inches.

In three other cases observed by the same surgeon secondary fracture occurred in young men who, in disobedience of instructions, left their beds and attempted to walk at about the fiftieth day. The practical conclusion is that after fractures of the femur patients should not be allowed to use the limb, even with crutches, until the seventieth or seventy-fifth day, notwithstanding apparent firmness of the union, and that splints should be kept for the same length of time upon patients whose obedience and reasonableness cannot be counted upon.

[1] Thèse inaugurale, Paris, 1822, quoted by Malgaigne.

[2] Clinique Chirurgicale de l'Hôpital de la Charité, vol. i. p. 389.

CHAPTER VIII.

TREATMENT OF FRACTURES.

The treatment of a fracture, strictly speaking, begins immediately after the accident that has caused it. Unfortunately for the patient, the first attentions are usually given, and his removal to his home or to the hospital carried out, by bystanders who do not fully appreciate the extent to which the injury already received may be aggravated by their well-meant but sometimes ill-judged interference. Or the patient himself, moved by a natural but equally harmful impulse to convince himself that he has not been seriously hurt, attempts to use his injured limb, and thus increases the displacement and the laceration. It is of great importance that this aggravation of the injury by unnecessary movements of the limb should be avoided; it is most liable to occur when the fracture involves the lower limb, and under such circumstances the patient should not be moved except upon a stretcher, and preferably after the application of a temporary splint. When a bone of the arm or forearm is broken sufficient immobility is obtained by supporting the limb with the other hand or in a sling.

Afer the clothing has been removed and the diagnosis made, the patient should be placed, if the fracture is of the lower extremity, upon a narrow bed furnished with a mattress and springs, not soft enough to yield noticeably under the weight of the body. If necessary, the firmness of the bed may be increased by placing planks lengthwise under the mattress. In cases of severe compound fracture of the femur it may be desirable to use a "fracture bed," of which there are many varieties in the market, designed to allow the bedding to be changed, the natural wants of the patient attended to, and the wound dressed without change of position. A simple arrangement which will meet the indications sufficiently well can be readily made with the aid of a carpenter. A stout rectangular frame, three feet wide and a little longer than the patient, is made and fitted with metal buttons or hooks at intervals of a few inches along the outer surface of its two sides, to which strips of stout cotton cloth six or eight inches wide can be attached by eyelets or cords. Two ropes, each about nine feet long, fastened by their ends to the four corners of the frame, complete the arrangement. The frame is placed upon the bed, and the patient upon it; when it is desired to raise him from the bed the slack of the two ropes is engaged in the hook of a pulley, the mate of which is attached to the ceiling immediately above the centre of the bed or to a frame constructed for the purpose. If the bands lying under the pelvis and upper portion of the thigh have been previously removed, the bed-pan can be conveniently used. The strips

can be changed by attaching a fresh one to the end of the one it is to replace, and drawing both through.

In the usual run of cases a bed-pan can be used without giving pain to the patient or disturbing the process of repair, and I have never found it necessary to use a device which, I fancy, is more frequently recommended than employed; that of cutting a hole in the centre of the mattress and lining it with some water-proof material. Sheets may be changed by folding half of the fresh one longitudinally, turning the patient slightly upon one side, placing the folded portion under him, turning him then upon the other side, and drawing the fold through; or by attaching the end of the fresh sheet to the upper end of the soiled one and working both down gradually to the foot of the bed, while first the shoulders and then the hips of the patient are slightly raised to aid the process.

Bed-sores are best guarded against by keeping the bed-clothing smooth and the skin dry, bathing exposed points occasionally with alcohol, camphor spirits, vinegar, or ether, mixed with twice the quantity of water, and by using inflated rubber rings under the pelvis. If they become imminent the affected surface should be painted with a thick coating of flexible collodion, and every effort made to protect it from pressure. If they occur they must be treated, according to circumstances, with emollient or stimulating dressings. When not otherwise contra-indicated the water-bed may be used with great advantage. Bryant says he has found a mattress divided into three parts, and a water cushion substituted for the middle section, of great use.

The aim of treatment is to secure prompt and firm union with the minimum of deformity and disability. It comprises two main indications: 1st, to reduce the displacement, to "set" the fracture; 2d, to maintain this reduction; and, while both these indications can sometimes be met with much ease, there are other occasions on which the former is impossible or the latter taxes the professional and mechanical skill of the surgeon to the utmost.

By the *reduction* or *setting* of a fracture is meant the restoration of the fragments to their normal positions and the consequent removal of such displacements as may exist. As most fractures of the limbs are accompanied by shortening, reduction is usually effected by traction, or, speaking technically, by *extension and counter-extension*, aided, when necessary, by lateral pressure to bring the fragments into line, *coaptation*, and by rotation to correct rotatory displacement. When angular displacement alone exists, as in incomplete fracture, lateral pressure upon the angle with the thumbs, while counter-pressure is made by the fingers grasping the limb above and below, is the means usually employed; and in longitudinal displacement with separation, as after fracture of the patella, the downward traction is made of course upon the upper fragment.

Usually considerable force must be exerted to overcome the contraction of the muscles which has followed or produced the displacement, but the amount of this force and its effectiveness vary within wide limits. The older surgeons found in the spasm of the muscles provoked by the traumatism, and in the acute inflammatory processes of the first stage, an argument for postponing all attempts to reduce the fracture until after the spasm and the inflammation had yielded to antiphlogistic treatment

and rest, but it is now well understood that the best means of subduing the one and preventing the other is be found in the early reduction of the displacement and the prevention of its return, and the general rule of treatment now is to set the limb at the earliest possible opportunity, usually at the first visit, whether it be immediately after the accident or only after the lapse of several days, using an anæsthetic, if necessary, to overcome the resistance of the muscles. The exceptions to the rule do not annul it entirely in the cases to which they apply, but only limit the degree to which it should be carried out. They are found in exaggerated muscular spasm and in acute painful inflammation of such an extent as to prevent the application of a retentive apparatus sufficient to maintain the reduction. The rule is positive to make as much reduction as can be made without using extreme force and as can be maintained without dangerous pressure upon the limb. It is a rule which is radically incompatible with routine practice and requires the best judgment and tact of the surgeon; its guiding principles are: 1st, that reduction, to any extent, diminishes *pro tanto* the irritation and reaction due to the fracture; 2d, that excessive force employed to accomplish reduction may cause additional lesions, the consequences of which are worse than those of displacement; and 3d, that more or less complete reduction is still possible one, two, or three weeks after the receipt of the injury, that is, at a time when two important obstacles to reduction, spasm and inflammation, have ceased.

The objection to the employment of extreme force lies in the danger of thereby rupturing an important vessel in case the resistance should be due to some mechanical cause, or of causing persistent pain, convulsions, or even tetanus if it is due to muscular spasm. Cases of death caused in both these manners are on record. Severe inflammation is a contra-indication to the use of force for two reasons: by involving the muscles it diminishes their extensibility greatly and thus opposes a mechanical obstacle that cannot be overcome without rupture of the stiffened fibres; and the exudation that accompanies it increases the bulk of the limb to such an extent that its forcible elongation results necessarily in a great increase of the tension under the enveloping fascia. The rupture of the muscular fibres adds to the existing traumatism and increases the chance of suppuration; and the tension may become so great as to cause gangrene by interference with the circulation. These are the dangers to be avoided and especially to be borne in mind when the use of an anæsthetic deprives the surgeon of the warning that would otherwise be given by the pain occasioned by the traction.

Ordinary muscular spasm can be annulled by ether or opium, but if the former is used care must be taken to prevent violent movements of the limb during the stage of excitement. In a case of fracture of the leg Broca overcame the spasm very cleverly by compressing the femoral artery for a few moments. The spasm, which had been so violent and painful that it was impossible to handle the limb, disappeared immediately; the limb was placed in an apparatus, and the spasm did not return until the dressing was changed. Pressure was then again made with the same success. This method promises sufficiently well to justify its use in some cases before recourse is had to anæsthetics; it enabled me to

reduce a fracture of the leg that would not yield to traction by the hands. Gradual, continuous extension by India-rubber, or by a weight and pulley, may be trusted to overcome any pure muscular spasm when it can be employed, but it is applicable only to cases where the seat of the fracture is sufficiently high upon the limb to allow the proper attachment of the bands. Spillmann[1] recommends as of occasional service the internal administration of atropia with a view to reduce the spasm, or the local use of an ointment containing belladonna and mercury when the spasm is associated with inflammation.

Inflammation is to be treated by reduction of the displacement, so far as possible, and by poultices. If it advances to suppuration the pus must be promptly evacuated and the fracture then treated as a compound one (q. v.). While waiting for the proper time to make complete reduction the limb must be immobilized by temporary dressings, with the fragments in the best attainable position, by the aid of fracture-boxes, cushions, inclined planes, or temporary splints.

Reduction is made, as has been said, by extension, counter extension, and coaptation; the first two, acting together, are intended to restore the limb to its original length by drawing the fragments past each other; the third is exerted transversely to bring them into line. There has been much discussion in the past concerning the position in which the limb should be held while reduction is made, some preferring extension, others flexion. Since the introduction of anæsthetics the question has lost much of its interest, but the fact remains that ordinarily the muscular resistance is less when the limb is partly flexed than when it is fully extended, and, therefore, that this position should be chosen whenever any important resistance is offered by the muscles. Practically, it is desirable that the limb during reduction should be in the position it is to occupy during treatment, in order to avoid the risk of reproducing the displacement during the change that would otherwise be necessary. Most fractures of the arm and forearm are reduced and treated with the elbow flexed, those of the femur with the knee extended, and those of the leg with the knee extended or slightly flexed.

Extension is best made by traction with the hands applied to the lower end of the broken bone, or to the distal segment of the limb if the fragment is too small to be readily grasped or if the limb is too tender. Counter-extension is made at similar distances from the seat of fracture by the hands of another aid, or by bands made fast to a neighboring fixed point. The surgeon meanwhile applies his own hands to the seat of fracture to appreciate the movement of the fragments, and to make coaptation at the proper moment. These general rules are, however, subject to many exceptions depending on the character of the displacement and the difficulties of the reduction. The traction should be moderate and, above all, steadily continuous; and, generally speaking, the fragments should be brought parallel to each other before the traction is begun; the latter is then made in the direction of the long axis of the limb. It should be continued for a few moments, while the surgeon watches the change in the length of the limb and in the relation of the

[1] Dictionnaire Encyclopédique des Sciences Méd., 4th series, vol. iv. p. 70.

fragments to each other, and makes gentle pressure on the sides of the limb to overcome lateral displacement. If the bone is superficial and the swelling moderate he may be able to recognize plainly the irregularities of the surface due to the displacement, and note their disappearance when the reduction is complete ; but if the bone is covered by thick muscles his only guide may be the length of the limb, of which he can judge by his eye, or by measurement. Sometimes reduction takes place with distinct crepitus, but the sign is of no great value, since it is sometimes absent in complete, and present in partial, reduction. While the effort is making the patient must be enjoined to maintain as complete muscular relaxation as possible ; he should be recumbent, and should not be allowed even to raise the head, and this quiescence should be maintained until after the retaining dressing has been applied.

It goes without saying that the reduction must include the other displacements, as well as the longitudinal and transverse, and in fracture of the lower extremity especial care must be given to the correction of rotatory displacement, and with that view the attention must be directed to the relations of the different bony prominences which may serve as guides, and they must be carefully compared with fixed and known standards, or with those furnished by the other limb.

It sometimes happens that complete reduction is difficult or impossible for other reasons than those already mentioned. Thus, when a small spongy bone or the expanded extremity of a large one has been crushed, so that there is an absolute loss of substance embracing the whole or only a portion of the thickness, either with or without impaction of one fragment in the other, it may be impossible to grasp the pieces so as to make the traction necessary to separate them, or to keep them, if separated, at a proper distance on account of the destruction of the intermediate portion. An instance of this firm impaction is reported by Stanley.[1] A man received a fracture at the lower end of the leg by the passage of a cart-wheel over it. All attempts to reduce the displacement were ineffectual, and after his death on the tenth day, and the removal of the soft parts by dissection, it was found difficult to separate the fragments, so firmly were they impacted. A similar case, of impaction at the lower end of the radius that could be overcome only by considerable force after dissection, has been reported by Dr. L. S. Pilcher.[2]

The same difficulty may be experienced after fracture of the diaphysis with much comminution, either because the small fragments become lodged between the large ones in such a way as to effectually oppose their adjustment, or because their minute shattering and compression produce the effect of an absolute loss of substance in their failure to afford support. Even when the comminution involves only a portion of the thickness of the shaft the same difficulty exists, because the remaining portions touch each other by too limited an area. Or the projections of a toothed fracture on one fragment may be engaged in other than their corresponding depressions on the other one, and the best efforts of the surgeon may be ineffectual to disengage them. Or, in an

[1] London Med. Gazette, 1844–45, vol. i. p. 274.
[2] Annals of Anatomy and Surgery, March, 1881, p. 116.

oblique fracture the anterior point, for example, may have been carried behind the posterior one, and the condition may not be recognized. Lisfranc is reported to have reduced the displacement in such a case by carrying the fragment laterally around the other, a manœuvre which could not be expected to always succeed even if the diagnosis were correctly made.

When the fracture involves the ankle-joint the external malleolus and foot may be dislocated outwards so far as to allow the astragalus to slip up between the tibia and fibula, as in figure 49, and to be wedged there too tightly to permit of reductien by the means usually at command. An example of this displacement, irreducible during life and verified by autopsy, is reported in the *Bulletin de la Société de Chirurgie*, 1880, p. 436. The patient was a woman, 58 years old, and had produced the fracture by an effort to draw off her boot with her hands, the foot twisting outward.

There are other cases, too, in which reduction cannot be made because it is impossible to act upon the displaced fragment on account of its small size, or of the depth at which it is placed. Examples of the first are presented in fracture of the patella, of the coronoid process of the ulna, and of other small apophyses to which powerful muscles are attached, and also of fragments, articular or otherwise, which have been displaced to a considerable distance. Examples of the second are seen after extreme displacement or rotation of the articular end of a long bone after its separation from the shaft by fracture; and a somewhat similar condition is found in fractures combined with dislocation. The same inability to properly handle the fragments is found also after fracture of the trunk or head, and frequently involves permanent deformity.

Finally, a serious obstacle to reduction may exist in the perforation of the overlying muscles and fascia by the sharp end of a fragment, or in the interposition of a bundle of muscle between the fragments. It is all the more serious because it is often difficult of recognition, and, when uncorrected, results in failure or retardation of union, or in union by an insufficient callus. An interposed bundle of muscle, if small, may become imbedded in the callus and disappear after a time by absorption, and therefore expectative treatment may properly be followed; but when the end of a fragment has penetrated a muscle to a considerable depth, the displacement must be overcome. The accident is most common in oblique fractures of the lower portion of the femur and of the upper portion of the humerus, the penetration being made by the lower end of the upper fragment in the former case, and by the upper end of the lower fragment in the latter. Recourse is first had to full extension in the hope of thus withdrawing the bone from the tissues in which it has buried itself. That failing, an operation becomes necessary sooner or later. It has been recommended and practised to insert a tenotome, divide the muscle below the end of the fragment by short cuts, and then to press the divided surfaces away, and thus open a route for the return of the bone to its place. In a case in which Laugier is said to have thus divided the perforated fascia of the thigh an abscess formed and led to the death of the patient by pyæmia. Nevertheless, I think few surgeons would hesitate now to cut freely down upon the bone, under

antiseptic precautions, for the purpose of correcting an otherwise irremediable displacement which, if left to itself, would cause complete disability. When the perforation involves the skin also, and the fracture is already compound, there can be no hesitation. Nothing is lost by enlarging the wound and thus gaining an opportunity to make the reduction intelligently, and, therefore, with the least laceration and violence. (See Treatment of Compound Fractures.)

Retention.—It occasionally happens that the tendency to displacement is so slight that, after the reduction of the fracture, the limb may be left without other dressing than such as may be designed to protect it from accidental violence. But in the vast majority of cases a dressing is required to resist the tendency of the muscles or of gravitation to produce displacement, and to secure immobility; and the same indications exist also in those cases in which only incomplete reduction is possible. The principles that govern the construction of the retaining apparatus are closely allied to, and sometimes identical with, those of reduction. In some cases the best retaining dressing is a moderate, continuous, active extension, supplemented by lateral support at the seat of fracture; in others it is rather a passive extension, that is, a fixed inelastic apparatus, which, while not making extension, resists retraction; in others, again, it is mainly lateral support to prevent angular or transverse displacement and to secure immobility. The details require that points of special pressure shall be guarded by cotton-batting, wool, or compresses, and that the limb shall not be wrapped circularly in such a manner as to expose it to gangrene. It may be necessary to bandage the distal portion of the limb to prevent œdema; but except under rare conditions when its use is clearly indicated, such as hemorrhage, *a roller-bandage should not be applied to the broken or upper portion of the limb under the splints.* If pressure is desired to reduce a swelling or moderate inflammation, it should be elastic or at least capable of yielding, if the pressure is increased from within, and, in addition, should be most carefully watched. The best material is cotton-batting applied smoothly and evenly under a bandage. Pain cannot be depended upon to give warning of too great pressure or impending gangrene; the fingers or toes should be left exposed to view, and the surgeon should make it an invariable rule to examine their sensitiveness and the circulation in them by pressure upon the nails and by feeling for pulsation in any accessible distal arterial branch immediately after a dressing has been applied, and at every visit for the first few days thereafter. If it is feared that the principal vessels or nerves have been injured by the accident, it is often best not to attempt complete reduction and retention at first, but merely to support the limb in a good position until the full extent of the injury shall have become apparent. In many litigations the question upon which the verdict depended has been whether the gangrene was due to the original injury or to an ill-applied dressing, and the surgeon should protect himself as far as possible against the doubt.

The choice of a dressing in simple fractures uncomplicated by severe injury to the soft parts depends in a measure upon the character of the displacement the tendency to which it is designed to correct; and

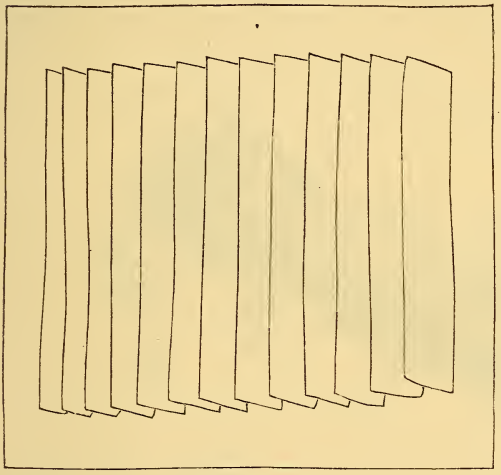
although many of the dressings and splints meet more than a single indication of this kind, and although, furthermore, an indication can usually be met in more than one way, it seems best to describe the dressings as nearly as possible in groups based upon this pathological difference. I shall describe only those that are now in general or occasional use, and shall leave some details to be noticed in connection with special fractures.

The first group comprises those which are intended simply to immobilize the limb or to effect contention by pressure, usually lateral. They are theoretically applicable especially to meet the tendency to transverse or angular displacement. The second comprises those which make active extension, or which maintain an extension previously gained. Their primary object is to overcome longitudinal displacements. These two forms merge into each other by intermediate forms possessing the qualities of both in varying proportions. Dressings are also classified sometimes according to the facility with which they may be readjusted or removed, as *movable*, *immovable*, and *amovo-inamovible* or *removable-fixed*. The first class includes all composed of bandages, cushions, and splints; the second includes those which harden after they have been placed upon the limb, such as the starch, dextrine, and gypsum dressings; and the third those composed of hardening materials arranged in sections that permit removal without destruction of the dressing.

The Scultetus Bandage (figs. 78 and 79).—This is a combination of short bands and wooden splints which was in very general use before the introduction of fixed dressings, and is still employed in some exceptional circumstances. It is composed of a large number of small bands, a broad cloth, two long wooden splints, and two long narrow cushions made of muslin stuffed with horse-hair, cotton, wool, or straw. It is prepared for use as follows: A piece of stout cotton cloth, of a length and breadth somewhat greater than the length and circumference of the limb that is to be immobilized, is spread out upon a table; then, beginning at its upper end, bands of the same material three or four inches wide, and one-half longer than the circumference of the limb are placed transversely upon it, each successive band overlapping the lower border of its predecessor about one inch. The cushions and the splints, each having about the length of the first piece of cloth, and a breadth of three or four inches, are placed along its sides, the edges of the cloth turned over them, and each rolled in until they meet in the centre. The bandage is now ready for transportation or use. If required, for example, for a fracture of the leg, the limb is raised from the bed, the bandage placed lengthwise under it so that its lower border projects a little beyond the foot, and is unrolled, and the limb lowered upon it. One end of the lowest transverse band is raised, carried over the front of the leg and around the other side as far as it will go, and its other end brought back over it in like manner. This is repeated with each successive band, and after all have been applied the splints are rolled up in the broad piece of cloth, one on each side, until they rest against the side of the leg, separated from it, however, by the cushions, and the whole is secured by a few strips of bandage. Sometimes a short anterior pad and splint are added.

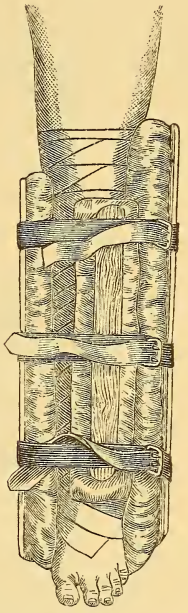
The advantages of the dressing are the facility with which the limb can be uncovered without disturbing it, and the equable and gentle pressure which it makes. Its disadvantages are its complexity, and its

Fig. 78.



The Scultetus bandage ready for use. The splints and cushions are not shown.

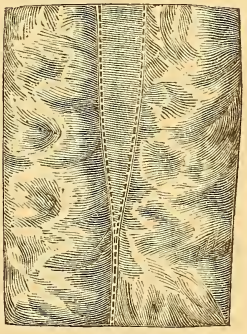
Fig. 79.



Scultetus bandage applied to the leg.

comparative inefficiency to prevent displacement. Its use is now generally restricted to cases which do not admit of a more efficient apparatus on account of inflammatory swelling, threatening gangrene, or extensive contusion, and to some compound fractures in which the antiseptic gauze is applied in this manner. It is seldom applicable except to fractures of the leg. It must be borne in mind that it is not incapable of causing strangulation of the limb, and therefore calls for the same watchfulness as other enveloping dressings.

Fig. 80.

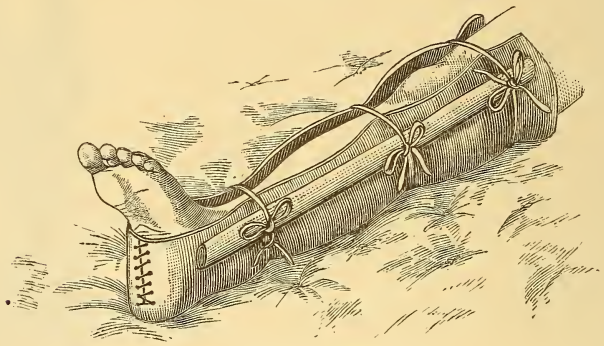


Bivalve cushion.

Bivalve cushion (figs. 80 and 81). This is a simple dressing that can be readily made of materials that are always at hand, and is therefore of great use to the country practitioner or in an emergency, and meets very well the indications of treatment during the first few days. It was invented by a French surgeon, named Laurencet. A rectangular sac of stout cotton cloth, of a length and breadth suited to the size of the limb, is divided into two parts by a seam which, beginning at the centre of its lower border, passes directly upwards for

one-third its length, and then bifurcates so as to leave a central V-shaped portion, the base of which is at the upper border of the sac, and is about three inches wide. The two lateral pouches thus formed are stuffed, and the openings closed. The limb is then placed along the centre, the two sides raised and supported by lateral splints, and the whole secured by the straps. If used in fracture of the leg, it is well to have the lower end of the sac project sufficiently beyond the sole of the foot to allow it to be turned in and fixed so as to support it. Valette speaks very highly of the firmness and security of this dressing;

Fig. 81.

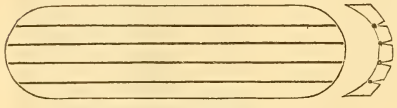


Bivalve cushion applied to the leg.

as the cushions are united to each other, they cannot become displaced with the facility which characterizes separate lateral pads and splints.

Wooden splints are made preferably of soft white wood which lends itself easily to the cutting and shaping necessary to make them fit. Their main use is as lateral or coaptation splints, padded or applied over cushions so as to fit accurately without undue pressure upon prominent points. They are also serviceable in some compound fractures to give the necessary solidity while allowing easy exposure of the wound. A splint is made by cutting the wood to fit approximately the limb in length and breadth; cotton cloth is then stitched loosely about it with an opening left at one end through which the padding, cotton, wool, curled hair, or some similar material, is introduced and distributed according to need, or cotton batting is laid upon the splint and secured by wrapping it with a bandage or thread. The carved splints prepared and offered for sale by dealers in instruments are vigorously condemned by most authors, and rightly so, in my judgment, if they are assumed to be fit for use in the shape in which they are offered. They need the same padding and adjustment that an improvised splint does, and their principal advantage is that, being already partly modelled, they need somewhat less. A convenient form for some cases is Gooch's flexible wooden splint, which is made of thin narrow strips pasted close together upon stout cloth or leather (fig. 82).

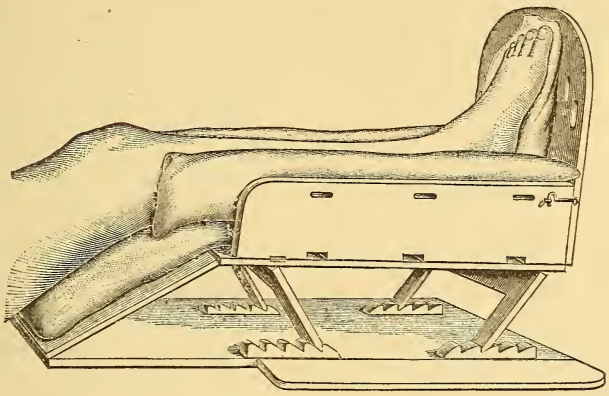
Fig. 82.



Gooch's flexible wooden splint.

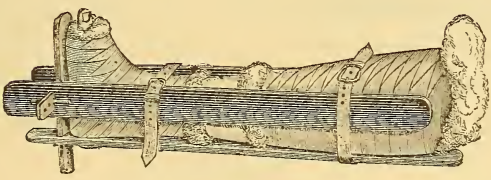
Fracture boxes are a variety of the wooden splint applicable to fractures of the leg. Their use in simple fractures is mainly a temporary one, because there are other and better permanent dressings, but they are frequently used in compound fractures throughout the entire period

Fig. 83.



Petit's fracture box.

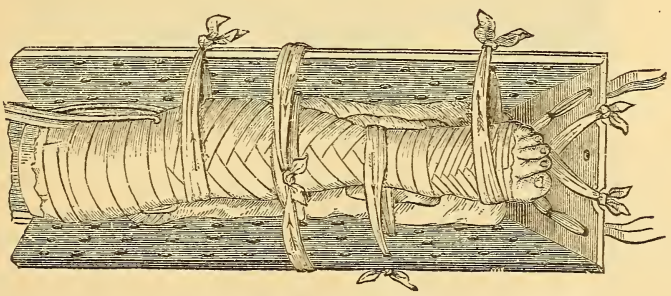
Fig. 84.



Scheuer's box splint.

of treatment. Figures 83, 84, and 85, show the principal varieties and render a detailed description unnecessary. They must be fitted with

Fig. 85.



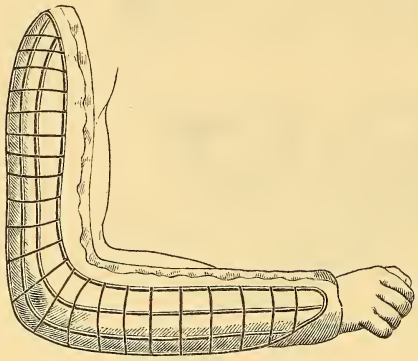
Baudens's fracture box.

cushions and pads for the reception of the limb, and with bands or straps to immobilize it and prevent displacements. It is well to support the

foot by a broad strip of adhesive plaster, which, beginning well up on the calf, is brought under the heel and along the sole of the foot, and tacked to the top of the foot-piece of the splint. By this means painful pressure upon the heel can be avoided.

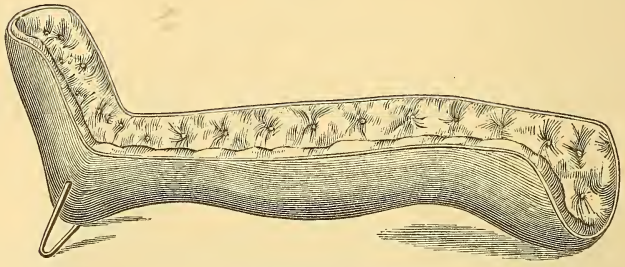
Gutters made of wire in a great variety of patterns are also in frequent use, and occupy a position intermediate between fracture boxes and moulded splints. A galvanized wire frame, or wire gauze strengthened at the edges, shaped to roughly fit the limb, is padded with cotton or cushions and bound on firmly by means of circular straps or bands. Those intended for the upper extremity are usually bent at a right angle at the elbow, those for the lower extremity straight or slightly bent at the knee, cut out at the heel, and fitted with a short cross-piece at that end to prevent rotation. Sometimes they are jointed at the knee or elbow, and in some cases the sides are hinged. Wire gauze is more commonly used now than wire frames, and the meshes of the latter should be smaller than those shown in figure 86. This mode of dressing has found its most complete expression in Bonnet's large gutters for the treatment of fractures of the thigh, which support the entire body, or in Palasciano's modification

Fig. 86.



Wire gutter for the arm and forearm.

Fig. 87.



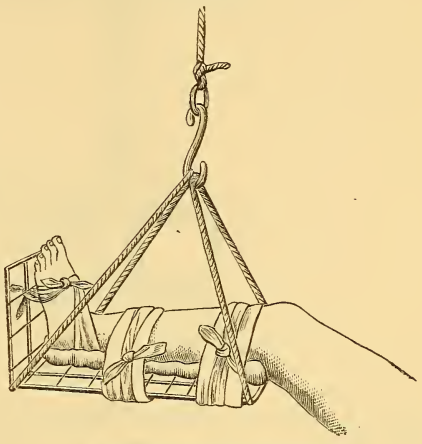
Bonnet's gutter for the leg.

which is jointed at the hip, and allows the limb to be placed in the extended or flexed position. The material yields sufficiently to lateral pressure to allow a certain amount of modeling to the irregularities of the limb, and as they are open in front an anterior pad and splint can be used if needed.

Posterior and *suspended splints* are classified by foreign writers as *hyponarthecic* (from ὑπό *under*, and ναρθηξ, *a splint*), a term which at first, as its etymology indicates, was applied only to posterior splints, but is now used to designate all suspended dressings. The aims of these

dressings are to maintain the limb, especially the lower one, in a flexed position, to permit movements of the body without disturbance of the fractured bone, and to enable the surgeon to examine all portions of the limb and to dress its wounds with the least disturbance and pain. The varieties are numerous, but follow two main types: a firm posterior splint or support upon which the limb rests; and an anterior frame or splint from which the limb is suspended by bands or sheets passing under it. In either case the splint is suspended from a cradle or a hook at a certain height above it.

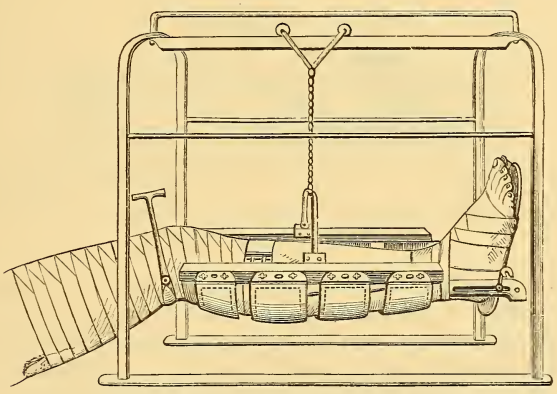
Fig. 88.



Mayor's suspension dressing.

The simplest, and, perhaps, the least efficient, is Mayor's (fig. 88), composed of a plank or wire frame suspended by cords attached to its corners. The limb rests upon it on a cushion and is immobilized by bandages fastened about the foot and different portions of the limb. McIntyre's splint provides also for continuous extension, and, combined with Salter's suspension cradle (fig. 89), is a favorite dressing. Nathan R. Smith's anterior splint (fig. 91)

Fig. 89.

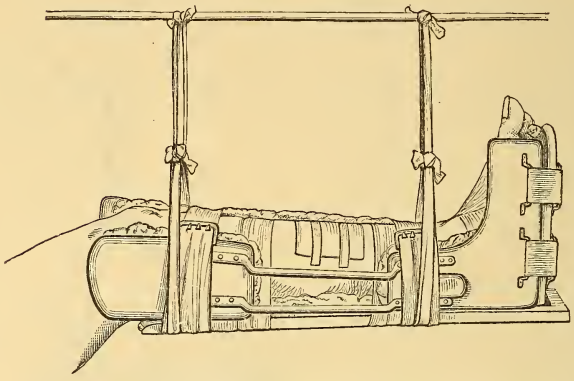


McIntyre's splint and Salter's swing.

was much used during the War of the Rebellion in the treatment of gunshot fractures of the thigh. It is composed of two parallel pieces of stout iron wire joined at the ends and by two or three intermediate rods, slightly flexed at the knee, and bent upwards at each end to fit the foot and the pelvis when the thigh is flexed. It is placed along the anterior surface of the limb and is bound to it by a roller bandage or

by straps. A pulley and rope furnished with two hooks provide for suspension. Hodgen's splint (fig. 92) is similar in construction, but

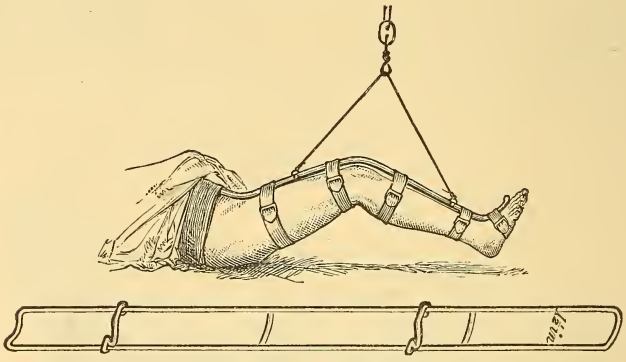
Fig. 90.



Suspended fracture box for compound fractures.

gives a firmer support and provides permanent extension in fractures of the thigh, if, as he suggests, the supporting hook is placed beyond the

Fig. 91.



Nathan R. Smith's anterior splint.

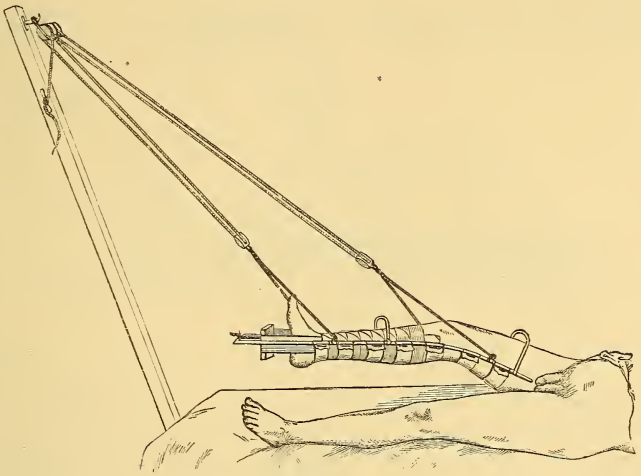
foot, or if it is fitted with an extension apparatus. Mr. Bryant[1] says, that in seventeen cases of fracture of the femur treated at Guy's Hospital by this splint the average shortening was less than half an inch, and that in six cases there was none. He found, however, after a lengthened trial, that a much larger amount of callus was formed than when he used the double lateral extension splint, and inferred that there was more mobility during treatment with the former than with the latter, and therefore discarded the Hodgen.

Hodgen's cradle (fig. 93) is also highly recommended for compound fractures of the thigh. It is made of four wooden bars diverging from

[1] Surgery, 3d Am. edition, p. 848.

a foot-piece and supported by a cross-piece at the knee. The limb rests upon bands which pass from one upper bar to the other, and are adjust-

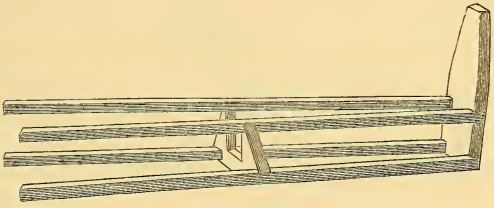
Fig. 92.



Hodgen's splint.

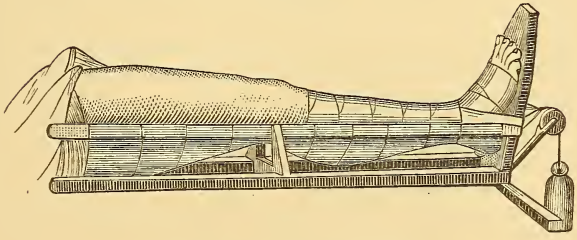
able at different lengths by pinning, or by knotting, to meet the varying size of the limb. Permanent extension by India-rubber, or by a weight

Fig. 93.



Hodgen's cradle.

Fig. 94.



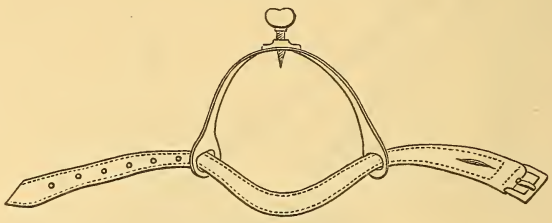
Hodgen's cradle with extension.

and pulley, can be used with it (fig. 94). (For adjustment of this method of extension see page 180.)

Splints made of plaster of Paris are sometimes used for suspension. Posterior ones are supported by bands; anterior ones by cords attached to hooks, or wires imbedded in the plaster. Their construction will be described subsequently.

Malgaigne's point (fig. 95) is used in fractures of the leg to overcome the strong tendency which sometimes exists in the upper fragment

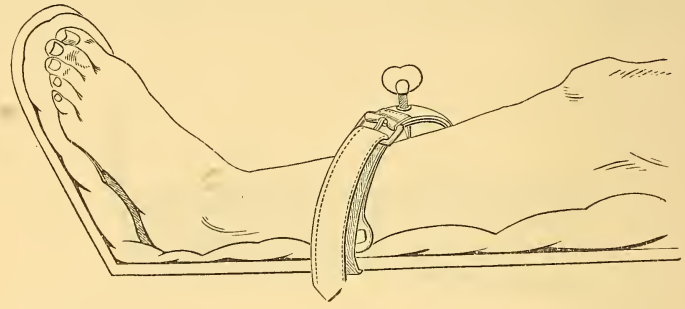
Fig. 95.



Malgaigne's point.

to project anteriorly. Malgaigne found that an iron pin forced through the skin into contact with the bone was well tolerated, giving rise to little or no pain or inflammation. Fig. 96 represents the instrument in place. In one case in which he used it a fatal erysipelas originated at

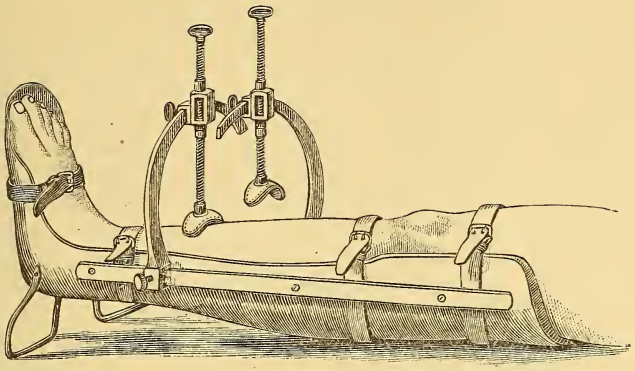
Fig. 96.



Malgaigne's point applied.

the wound, and this fact has brought some discredit upon the method, which, moreover, does not commend itself readily to the patient. It meets the indication very well, and I should not hesitate to use it in any case where the displaced end of the bone threatened to cause perforation and could not be otherwise reduced. It has been sought to obtain the same result by means of local pressure with a pair of padded rods, changing the pressure frequently from one to the other, so as to avoid sloughing at the points pressed upon. Fig. 97 represents such an apparatus; but experience has shown that they are generally inefficient, because, notwithstanding the alternation, the skin is usually unable to bear the irritation. In fact, Malgaigne's point was devised as a substitute for the other.

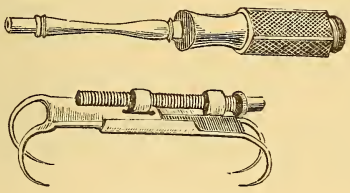
Fig. 97.



Anger's apparatus for alternate pressure.

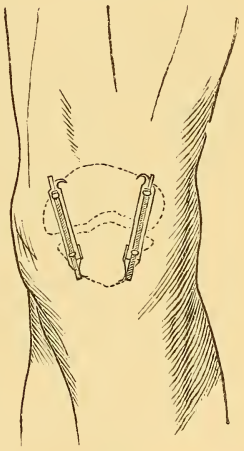
Malgaigne's hooks (fig. 98) are designed to hold the fragments of a broken patella together. They are a pair of hooks united by a movable

Fig. 98.



Malgaigne's hooks.

Fig. 99.



Levis's modification in place.

screw. The points of one pair are forced through the skin and engaged in the upper fragment, those of the other in like manner in the lower, and the two are then joined and brought together by the screw. Vallette substitutes for the hooks a pair of forks attached by movable screws and rods to a gutter in which the limb lies; and Levis prefers two separate sets of hooks (fig. 99), because they allow a more accurate adjustment to the irregularities of the bone.

Moulded splints are constructed of any material that can be made temporarily soft enough to take accurately the shape of the part to which it is to be fitted, and which then becomes and remains hard enough to retain the shape that has been thus given to it. The materials most frequently used are pasteboard, leather, felt, gutta-percha, and plaster of Paris.

Pasteboard or binder's board owes its availability to its quality of softening when placed in hot water, and of regaining its stiffness when it becomes dry. One or two strips, according to circumstances, are cut after a pattern made in paper, placed for a moment in hot water, moulded carefully to the limb, and secured in place by lateral splints and a roller

bandage until dry. When it is necessary to mould pasteboard at a right angle, as at the shoulder, longitudinal slits should be made in it, or V-shaped pieces taken out, since creases diminish the stiffness and make the pressure of the bandage uneven by their varying thickness. Care must be taken not to make the pasteboard too soft, for it then tears easily and, by losing some of its starch, becomes unable to regain its original stiffness. The details of its application, in a fracture of the leg, for example, are as follows: A pattern is made in paper of the lateral half of the leg and foot, and two strips of pasteboard cut according to it, of such dimensions that when fitted to the limb they cover the sides, but do not quite touch each other in front and behind. Reduction is then made, and the limb surrounded with a loose bandage, preferably of flannel, or with a thin layer of cotton batting; the two splints, softened by immersion in hot water, are placed one on each side and moulded approximately to the leg and foot by gentle pressure with the hands, and then a roller bandage is snugly applied over them from the toes upward. This makes the fit accurate and close. Lateral wooden splints properly padded are placed on the sides and secured by bands or a roller bandage. Additional security is given by rolling up these lateral splints in a broad sheet of cotton cloth, as in the Scultetus bandage, the portion of the sheet between them passing under the limb. The pasteboard becomes dry in twenty-four hours, and then the lateral splints may be discarded.

Moulded splints of leather, felt, or cloth stiffened with shellac are prepared and adjusted in like manner. Those stiffened with shellac can be softened by dry heat, but they become flexible only at a comparatively high temperature, and stiffen rapidly in cooling. It is therefore necessary to protect the limb against the heat by compresses or padding, and to make the adjustment rapidly.

Gutta-percha is used in sheets or strips of the same length and breadth as the other materials, and from one-sixteenth to one-fourth of an inch in thickness, according to the size of the broken bone. It is softened by immersion in hot water, and Dr. Hamilton recommends that a large tray should be used for this purpose, in which the gutta-percha can be placed wrapped in a sheet of muslin. It becomes sticky as it softens and adheres to the muslin, which then serves to protect the hands of the surgeon and the skin of the limb. If too hot and soft it must be slightly chilled by sprinkling it with cold water, and then rapidly moulded upon the limb. It hardens in fifteen or twenty minutes, and the process may be hastened by sponging it with cold water.

Plaster of Paris or *gypsum* was first employed in Western Europe in the treatment of fractures early in the present century, having then been introduced from Turkey, where it seems to have been in use for a long time. It was used to make a solid mould about the limb by placing the latter, well-oiled previously, in a box and pouring in enough plaster to cover either the limb entirely or only its posterior two-thirds. The method was objectionable on so many accounts that its use never became general, and it was only after the introduction in 1852 and 1853 by the Holland army surgeons Mathysen and Van Loo of the method of applying it by means of bandages soaked in the cream that its availability and usefulness became apparent, and it earned the favor in which it is now

so widely held. It is used now in the form of anterior, posterior, and lateral splints moulded accurately to the limb, or as a complete encasement in simple fractures, and as a fenestrated or interrupted dressing strengthened by iron rods or bands in compound fractures.

The application is usually made in one of two manners: either roller bandages of coarse cotton, or preferably of the thin open-meshed material known in commerce as crinoline, are filled with the dry powder and moistened when needed by immersion in water; or bands or sheets of the same materials or of coarse flannel are soaked in plaster cream and then applied to the limb. The former method is used for complete encasement or interrupted dressings, the latter for moulded splints. The plaster should be fresh and perfectly dry, for if it has been so exposed as to absorb a certain amount of moisture from the air it is slow, or may fail entirely, to harden. Plaster damaged in this manner can be restored by thorough drying in an oven or over a fire. Roller bandages are prepared by unrolling them, rubbing the dry plaster thoroughly into their meshes, and re-rolling them; if not to be used immediately, they can be preserved for a long time unchanged by wrapping them in oiled paper or by keeping them in a closely covered tin box. When needed for use, they should be placed on end in water deep enough to cover them, and gently pressed to force out the air; on removal the excess of water should be squeezed out. Plaster cream is prepared by placing the quantity of water judged necessary in a basin and slowly sifting the dry plaster in until the mass reaches the surface. It should not be stirred, for stirring hastens the "setting." If it is desired to delay the setting beyond the usual time, a pinch of cream of tartar may be added to the water, or a little gelatine, two or three parts to a thousand of water. The addition of common salt or the use of hot water hastens the setting.

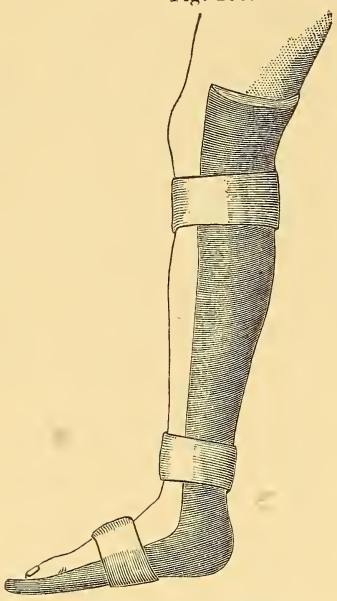
Moulded plaster splints are best made of from eight to fifteen thicknesses of crinoline folded to form a rectangle of suitable size or cut to the desired shape. Before being placed in the plaster cream they should be dipped in water and thoroughly wrung out; then they are partly unfolded, or, if made of separate pieces, divided into portions of two or three pieces each, passed through the cream, which is well rubbed into them, or the cream applied with a spoon, refolded or replaced together, stripped down between the hands to remove the superfluous water, and applied to the limb directly or with an intervening compress. At points where the splints need to be bent at a considerable angle, as at the heel, elbow, or shoulder, they should be cut partly through in the line that would be taken by the folds if they were not cut, and the edges of the cut interlaced. It is well to make the cuts in the different layers in lines that do not exactly correspond with each other, in order that the subsequent union may be more uniform and solid. A simple fold at such a point diminishes the solidity of the splint. The application of a dry roller bandage outside the splint insures retention of the shape and hastens the setting. If there is any tendency to displacement of the bone, reduction must be maintained by the hands until the hardening is complete.

Splints thus prepared may be made impervious to water by brushing them over several times with shellac varnish or by pouring melted paraffine upon them; the varnish and the paraffine, if sufficiently hot, will

soak through the entire thickness of the splint and protect it perfectly from subsequent shortening; or the splint may be removed and the paraffine applied on the inside as well as on the outside. This precaution is very desirable when the fracture is complicated by a suppurating wound in order to preserve the solidity of the splint and avoid the necessity of changing it on account of its saturation with the decomposing discharges. Another, but inferior, method is to place a piece of oil-silk between the limb and the splint and reflect it over the edge of the latter.

The splints may be anterior, posterior, or lateral, and the former may be readily fitted for suspension by imbedding in them hooks, or stout telegraph wire bent to form projecting loops at convenient distances. They may also be made somewhat lighter without loss of strength by placing thin strips of tin, wood, or iron longitudinally between their folds, and omitting some of the layers of the cloth. The posterior splint (fig. 100), combined with a single or double lateral one, is very serviceable in fractures of the lower end of the leg; the posterior splint should be long enough to reach from an inch above the toes around the heel nearly to the knee, or better, perhaps, three or four inches above it; and the lateral one should be wrapped first about the instep and then carried up the leg to the same height as the other, or it may be double, passing under the instep like a stirrup. The projection of the posterior splint beyond the toes serves to keep the weight of the bed clothing from them. MacCormac recommends a combination of anterior and posterior splints for fractures of the leg, either simple or compound. The shape of the splints and the appearance of the limb when thus dressed are shown in figs. 101 and 102. The splints must be narrow enough not to come into contact with each other at their edges.

Fig. 100.

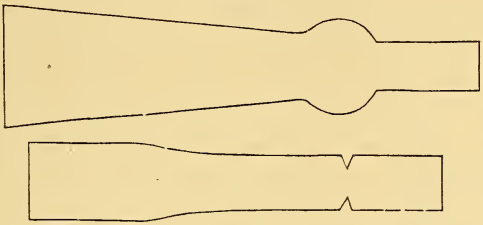


Posterior gypsum splint or gutter.

The Bavarian, book-back, or bivalve plaster splint (fig. 103), is designed to afford a convenient means of inspecting the broken limb during the treatment. It is made of two pieces of coarse flannel that has been shrunk and cut of the proper length and of a width somewhat greater than the circumference of the limb. These pieces are then fastened together by two rows of stitching about half an inch apart along the centre, which, in the case of the leg, is to occupy the posterior median line, and placed in position under the limb. The one that is next to the leg is then folded around it and its free edges stitched together in front and along the dorsum and sole of the foot, plaster cream is spread smoothly over it and well rubbed in, and the outer layer of flannel then drawn over and stitched or pinned fast in like manner.

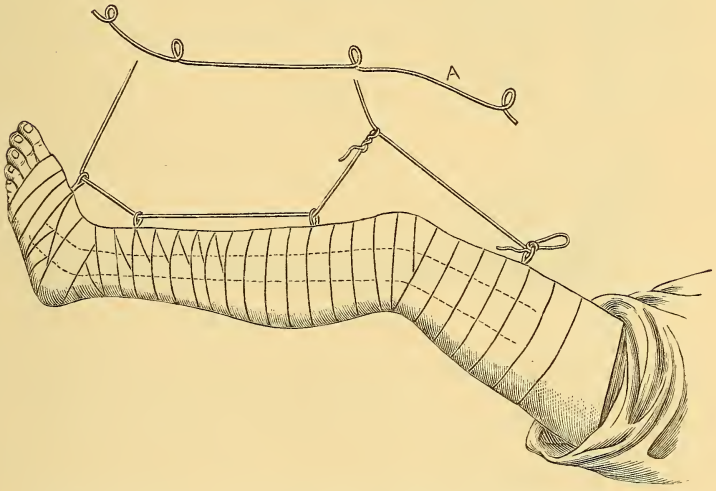
After the plaster has set the stitches are cut, the excess of flannel cut away, and the edges bound by stitching those of each side together, or

Fig. 101.



Strips to form anterior and posterior plaster splints for the leg.

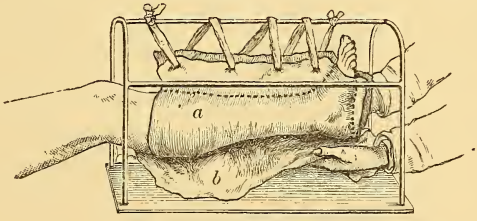
Fig. 102.



The above applied. *A*, is a wire bent into loops for the purpose of suspension.

by binding on strips of leather provided with eyelets. The bandage is kept in place by a bandage or by a cord passed through the eyelets, and

Fig. 103.



The Bavarian splint.

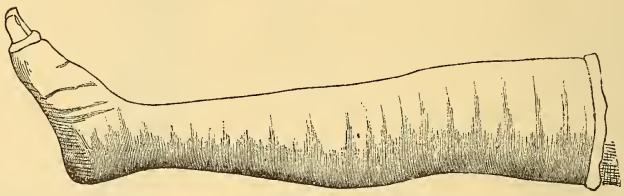
can be readily removed, or one side can be lowered by turning it on the hinge which is formed by the narrow strip left between the two rows of

stitching behind. Mr. Bryant uses instead of plaster a mixture of precipitated chalk and mucilage of gum acacia.

Zsigmondi,[1] of Vienna, recommends a splint made of a flat bag of the proper shape and filled with dry plaster. The bag is made of two pieces, one of cotton and one of shrunk flannel, sewed together with an interposed piece of muslin of the same size. The two pouches of the sac are then filled with dry plaster spread evenly through them, and the whole dipped into warm water. The air escapes through a small opening left at the end where the plaster was introduced, aided by gentle pressure with the hands. The sac is removed from the water, allowed to drain for a moment, laid upon a table and pressed out evenly, then applied to the limb with the flannel next the skin, and fastened with a roller bandage. Angles in the limb are provided for by previously cutting out V-shaped pieces at the corresponding points in the sac and sewing the sides of the gap together, flannel to flannel, and cotton to cotton.

Complete encasement of a limb in plaster of Paris (fig. 104), the dressing that is generally meant when the expression "treatment by plaster of

Fig. 104.



Encasement of the leg in plaster of Paris.

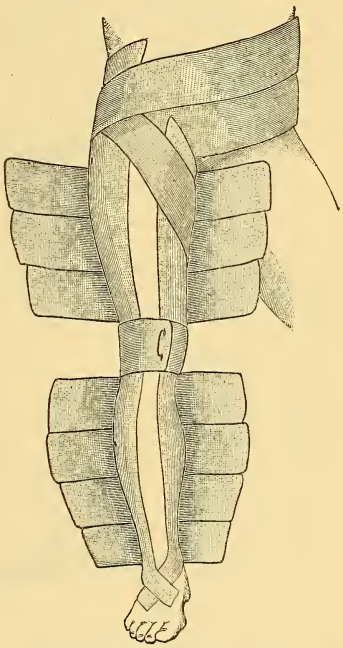
Paris" is used with reference to a fracture, is a dressing of great value. Introduced as a substitute for the starch and other "immovable" dressings, it inherited both their favor and disfavor, but by its general superiority to them and by the ease with which it lends itself to the treatment of compound fractures and operations upon the joints it has established its position, and is now in very general use, at one period or another of the treatment, although it has suffered somewhat from the exaggerated claims of its extreme partisans. The mode of application is as follows: after reduction of the displacement by extension the limb is enveloped in a sheet of coarse blanketing cut to fit it accurately, or by short roller bandages of the same or a similar material loosely applied, or, still better in my opinion, in a layer of cotton batting reinforced over the depressions and about the bony prominences and supported by a few turns of a roller bandage. Then the roller bandages, prepared as above described (p. 171), are applied in the usual manner from below upwards until a sufficient thickness has been obtained. They must be simply rolled around the limb, not drawn tightly. The limb meanwhile is supported and extension maintained by assistants, the bands are rubbed smooth by the surgeon, strips of thin wood or metal interposed at intervals to increase its strength, if necessary, or a wire for suspension, and when

[1] Bulletins de la Société de Chirurgie, 1878, p. 653.

the dressing is completed the limb is lowered upon the bed and the extension maintained until the plaster has set. In fracture of the leg or thigh the comfort of the patient can be increased by the use of Volkmann's sliding rest for the foot. (See page 182.)

In the lack of prepared roller bandages, or of the material spoken of as most fit for their construction, the dressing can be made of layers of any coarse cloth, as shown in fig. 105, and soaked in plaster cream.

Fig. 105.



Plaster-of-Paris dressing made of coarse sack cloth. (Esmarch.)

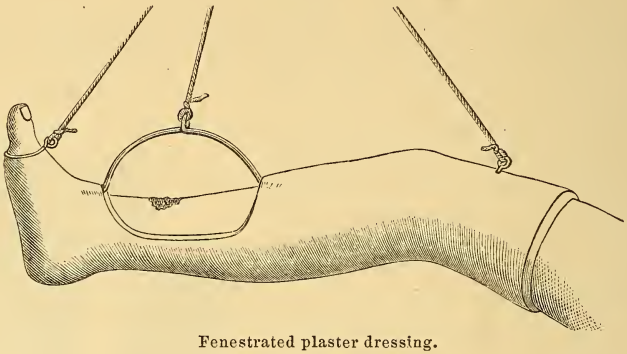
A properly applied dressing should not only cause the patient no pain, but should produce even a feeling of relative comfort. Some sensitiveness may persist for a short time at the seat of fracture, but if it has not disappeared or become much less by the following day the cause should be sought for. If this seems to be tightness of the dressing, if the circulation in the exposed fingers or toes is interfered with, as shown by change of color, œdema, or loss of sensation, the dressing must be removed, or at least laid open longitudinally, to relieve the pressure and allow inspection.

In fractures complicated by suppurating wounds fenestræ must be cut, which can be done with a sharp knife without much trouble, and the edges protected by shellac or paraffine. In order also to prevent saturation by the discharges of the cotton or blanketing that lies next the skin two or three pieces of oil-silk considerably larger than the wound should be placed upon it, and then, after the fenestra has been made, slit in different directions, turned out over the edge, and fastened down with varnish or collodion. If the wound is to be dressed antiseptically, or if the injury is severe and burrowing of the pus is feared, a fenestra of sufficient size would weaken the splint too much, unless its place were supplied by other means, and therefore bent rods or bands of hoop-iron must be imbedded in the dressing during its application, so as to bridge over the opening. These "interrupted" splints (figs. 106 and 107) are of many forms, and afford opportunities for the exercise of much ingenuity and skill in their construction. The connecting rods should be stout, and if bands are used they should be so placed that their breadth, and not their thickness, shall be opposed to the expected strain. It is usually necessary therefore to have at least two of the latter, placed in planes that cross each other at or nearly at a right angle. A broad, stout posterior splint of iron imbedded in the plaster, and not bent like the others, gives much additional strength (fig. 107).

Similar fixed dressings are made with starch, dextrine, and silicate of soda or potash. Their principle is the same, and each has its own spe-

cial advantages and disadvantages. The starch bandage, generally known in literature as Seutin's, and antedating the others, is made by

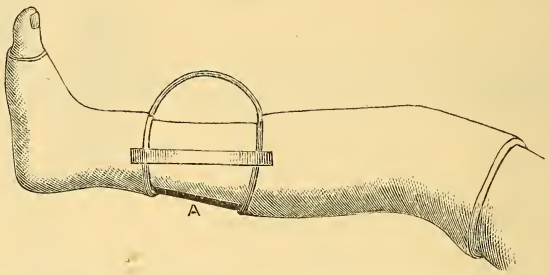
Fig. 106.



Fenestrated plaster dressing.

wrapping the limb in a roller bandage after protecting the bony prominences with cotton, and then applying numerous rollers saturated with

Fig. 107.



Interrupted plaster dressing. *A*, the straight posterior iron splint.

starch, and having longitudinal and spiral strips of pasteboard interposed between the layers. It requires about forty-eight hours to harden completely, and during this time the reduction must be maintained by appropriate external splints. After hardening, the dressing is divided longitudinally and refastened with a bandage if it is found to fit properly, relaxed if too tight, or made tighter if too loose, by cutting out a strip along the line of section. The substitution of a tolerably thick layer of cotton batting for the first roller bandage is a valuable modification. Dextrine was substituted for the starch by Velpeau, because it hardens more rapidly, within a few hours. It is obtained in the form of a powder, which must be prepared for use by mixing it first with alcohol, and then reducing it with hot water to the proper consistency. Roller bandages are then unrolled and re-rolled in it, squeezed thoroughly, and applied to the limb in the usual manner over a dry bandage or a layer of cotton. I have found it more troublesome to use than plaster, and quite as objectionable on the score of uncleanliness; its superiority to plaster is in its lightness.

Silicate of soda or potash (water glass) hardens more quickly than dextrine, is equally light, and is ready for use in the form in which it is obtained. It is a clear, slightly amber-colored, syrupy liquid, with which the roller bandages are saturated in the same manner as with dextrine; it is less rigid than plaster, and it has occasionally happened that extensive sloughing has been caused by its contact with the skin.

Quite recently Von Langenbeck[1] has recommended a new cement, known as tripolith, as a substitute for plaster. He claims for it that it remains unaffected by the air, while in the condition of powder, for a longer time than plaster, that it is 14 per cent. lighter, hardens more rapidly, is a trifle cheaper, and when once hard and dry is impervious to water. It is applied in the same manner as plaster. Its composition is a secret, and it is manufactured for use in stucco work. I do not know if it can be obtained in this country.

The advantages of the plaster dressing, as compared with the other immovable ones, excepting tripolith of which I have no experience, are: 1st, that it hardens so rapidly that reduction can be easily maintained for the necessary length of time without the aid of splints; 2d, that it is, on the whole, more solid, and therefore better able to prevent subsequent displacement; 3d, that it is sufficiently porous to allow some ventilation of the limb; 4th, that it is simple and cheap. Its disadvantages are its weight, its destructibility by water, and the impossibility of removing it temporarily. If such removal is required a new dressing must be made, or the original one must be made in the form of two or more splints, as above described. It ought to be unnecessary to add that it can yield no better result in the way of shortening than can be obtained at the time of the reduction; the most that it can do is, of course, to preserve the length that exists at the time it is applied, but in the controversies to which it has given rise this fact seems to have been lost sight of occasionally on both sides, and the relative merit of the dressing has been judged by the results found at the end of treatment, without consideration of the characteristics of the recent fracture. Its efficiency depends also in great part upon the existence of suitable points for counter-pressure; the mere encasement of a limb in plaster will not prevent shortening if the limb can move longitudinally within its case; the soft parts cannot be depended upon to prevent this motion, because they shrink somewhat during the treatment, and the limb lies loosely within the dressing. Bony points or surfaces inclined at an angle to the longitudinal axis on each side of the fracture are alone sufficient, and these cannot always be found, or made use of. For this reason, while the dressing is excellent for fracture of the leg, it cannot be depended upon with certainty in fracture of the thigh or of the humerus, because in both these cases it is difficult to obtain an upper fixed point, and I therefore prefer to postpone its application in a fracture of the thigh until after the third or fourth week, when the partial consolidation of the callus aids to prevent shortening. Some surgeons, however, use the immovable apparatus, either of starch or plaster, in all simple cases of fracture of the thigh from the very beginning, and do not keep the patient in bed

[1] Berlin. Klinischer Wochenschrift, 1880, No. 46.

for more than three or four days. Erichsen[1] says he has treated many in this way "and without the slightest shortening or deformity being left. The points to be especially attended to are, that the back pasteboard splint (in the starch dressing) be very strong, at the upper part especially, and that the spica be well and firmly applied, so that the hip and the whole of the pelvis may be immovably fixed."

The liability to gangrene, general or local, due to its use, has, I think, been overestimated in consequence of a few unfortunate cases, in some of which, even, the real agency has perhaps not been recognized. I have known the perineum to slough deeply in consequence of the pressure made upon it by the edge of a dressing applied for a fracture of the femur, and that is an illustration of the difficulty just mentioned of finding an upper fixed point in such cases, and I have treated a fracture of the leg that had become compound by the sloughing of the skin under the plaster, but in this case the sloughing was attributed to the coexisting contusion rather than to undue pressure made by the splint, and from what I could learn of the conditions I am inclined to think it would have occurred if the fracture had been treated in any other manner. In short, it is blind partisanship that claims for plaster success under all circumstances, and it is equally blind prejudice that holds it responsible for all complications that arise under it. Like any other dressing, it must be used judiciously and not in a routine manner, and its limitations as well as its merits must be recognized. I should hesitate to apply it immediately after the accident if the patient could not be frequently seen during the next forty-eight hours, and although the cotton or blanketing placed under it is, in the immense majority of cases, a perfectly efficient precaution against excessive local pressure, yet it must be remembered that extensive sloughing has occurred under such circumstances and is inexplicable on any other theory than that of pressure except by resort to unsubstantiated suppositions of nerve injury. It is well known that early reduction and perfect retention diminish materially the subsequent inflammatory processes, and therefore, since the plaster dressing is in suitable cases the most efficient means of retention, it should be applied at the earliest possible moment, and as the only danger is that of undue pressure, watchfulness ought to be a sufficient protection. The interposition of a thick layer of cotton is an absolute guarantee against this danger but diminishes the accuracy of the retention.

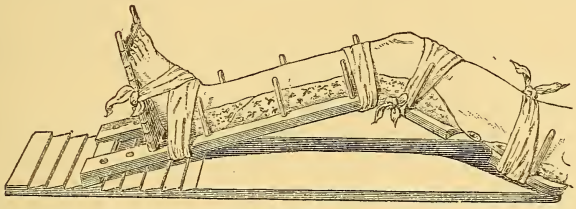
Gurlt[2] recommends the immediate application of the plaster very strongly on the ground that, so far from causing gangrene, it acts as a most efficient antiphlogistic by virtue of the equable pressure which it exerts, as well as by its immobility. He recognizes certain exceptions in which the dressing must be used with caution, if not entirely rejected. These are: present or impending gangrene; extravasation of blood sufficient to stretch the skin notably; injury of a large artery, making the formation of a false traumatic aneurism probable; and, finally, the existence of acute erysipelatous or phlegmonous inflammation.

[1] Science and Art of Surgery, Am. ed. 1873, vol. i. p. 377.
[2] Loc cit., vol. i. p. 472.

It has been alleged that failures of union are more common in fractures treated with plaster, but the allegation appears to be unfounded.

The double-inclined plane (fig. 108) is designed to maintain reduction after fracture of the femur by continuous extension supplied by the weight of the pelvis. It consists essentially of two posterior splints, femoral and tibial, united by a hinge at the knee, and kept at the chosen

Fig. 108.



Esmarch's double-inclined plane.

angle by a horizontal plank upon which it rests, or by a rod, or by straps, or by suspension of the tibial portion. The limb rests on cushions placed upon the splint and is fastened to it by bandages or by lateral pegs inserted vertically. It is essential that the femoral splint and the horizontal plank shall not support the pelvis; this must be left free to sink into the mattress and thus furnish the desired extension. Mayor modified this apparatus by making it of wire and broad enough to bear both limbs, using the uninjured one as a sort of splint to secure the other in a good position. Mr. Bryant says he has found it very valuable in fractures of the upper third of the femur where the upper fragment is apt to tilt forward and rotate outwards, but it should be used only when other means fail, and it is daily dropping out of use.

The treatment of fractures by continuous extension applied to the distal segment of the limb has been in use for centuries, the means employed being a weight and pulley or an adjustable screw passing through the foot piece of a long splint in fractures of the thigh, for example. Counter-extension was maintained by a perineal band attached to the head of the bed in the former case, and to the upper end of the long splint in the latter. The disadvantages were serious; if the extension was efficient the pressure produced upon the dorsum of the foot and about the ankles by the bands through which it was made caused pain and, if prolonged, sloughing; if moderate enough not to cause this result it was insufficient to prevent shortening, and the surgeon's time was spent in alternately increasing and diminishing the traction to meet first one and then the other indication. The patient too often found his convalescence retarded by a slough and his limb permanently shorter by one or two inches.

The first important modification was the substitution of long strips of adhesive plaster for the bands and girdles by which the weight or the screw was attached to the limb. This device entirely prevents pain and eschars, and allows the use of a traction of twenty or twenty-five pounds

without serious inconvenience to the patient. It appears to have been first[1] employed not infrequently in Pennsylvania before 1848, and published by Sargent[2] at that date, and again independently by Dr. Josiah Crosby, who published it in the *Transactions of the American Medical Association* in 1850 (vol. iii. p. 382), but its popularization seems to have been due to Dr. Gurdon Buck, who introduced it on Dr. Crosby's suggestion into the N. Y. Hospital before 1852. In 1855, a specimen of the thigh splint as then used in the N. Y. Hospital was given by the late Dr. Suckley to Nélaton, and another was taken at the same time by Prof. C. R. Agnew to Dublin.[3] This was its introduction into Europe, and this method of making extension is frequently spoken of in foreign works as the "American method" of treating fractures.

The next step in the development of the dressing here in America was the adoption of short coaptation splints and the discarding of the long splint and of the perineal band, and reliance upon the weight and pulley for extension, and upon the elevation of the foot of the bed to make counter-extension by the weight of the body sufficient. The raising of the foot of the bed was suggested by Dr. Van Ingen, of Schenectady, N. Y., in 1857,[4] and, like the extension by adhesive plaster, was adopted and popularized by Dr. Buck. Dr. Hamilton still uses the long splint with a cross-piece at the foot to prevent rotation (fig. 113), but Volkmann's sliding rest (fig. 112) answers the purpose equally well and possesses additional advantages of its own. The substitution of an elastic for the rigid cord to suspend the weight seems to me of no importance if the pulley moves freely. Elasticity in the means of traction is of value only when one of the points is fixed; as it can neither increase nor diminish the force exerted by a freely movable weight it adds nothing to the constancy or equality of the extension, and if it yields more readily than the weight alone would to a sudden twitch of the muscles it may be disadvantageous rather than useful by allowing a momentary mobility that the weight might prevent.

In England and in France the long splint has been retained, and the extension is made more generally by an India-rubber cord with diverse methods of counter-extension than by the weight and pulley.

The principle of the method of treatment by continuous extension is to tire out the muscles whose contraction causes displacement by a moderate but persistent strain upon them, one from which they are not relieved for several weeks. Its principal and most important use is in fractures of the shaft of the femur, but it may be used whenever the indications exist and a sufficient and suitable surface can be found for the attachment of the adhesive plaster, and when proper counter-extension

[1] The use of adhesive plaster by Gooch about one hundred years ago, referred to by Martin in the North Carolina Medical Journal, January, 1878, and by Prof. Van Buren in the N. Y. Medical Record, 1878, p. 242, and quoted by Dr. Hamilton in the sixth edition of his work, does not seem to justify the claim to priority made in his favor, for he used it, not to make extension in fractures, but only to flex the heel upon the leg after rupture of the tendo Achillis, just as it is used to draw together the sides of a gaping wound.

[2] Minor Surgery, Phila., 1848, quoted in a note of Crosby's paper.

[3] Van Buren, in N. Y. Medical Record, 1878, p. 241.

[4] Trans. Am. Med. Ass., vol. x. 1857, p. 436; quoted by Van Buren, loc. cit.

can be made. Such uses will be described in connection with the different fractures to which they are applicable, and I shall mention here only the details of its use in fractures of the thigh.

A band four or five inches wide of stout moleskin adhesive plaster, long enough to reach from a point on the side of the thigh a few inches above the knee loosely around the sole of the foot and back to a point opposite that at which it began, is notched in its middle portion and slit at the ends as shown in figure 109; a flat piece of wood, five by three

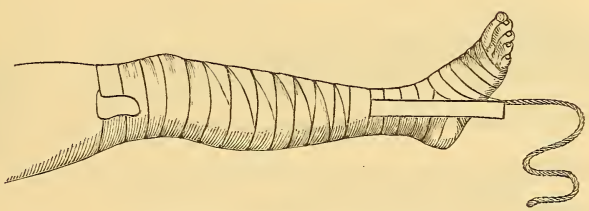
Fig. 109.

inches and perforated in the centre, is secured in the centre of the strip by folding the edges of the latter over it, the folds being continued up to the notches (fig. 110) so as to cover in the adhesive surface of the

Fig. 110.

intermediate portion. The piece of wood must be longer than the distance between the malleoli. A roller bandage is then applied to the foot, ankle, and lower third of the leg, the plaster placed on the sides of the limb above it, the foot-piece being about two inches below the sole of the foot, and secured there by carrying the bandage up over it; the upper ends of the plaster, if long enough, may be turned down and covered by a few additional turns of the roller. It is very desirable

Fig. 111.



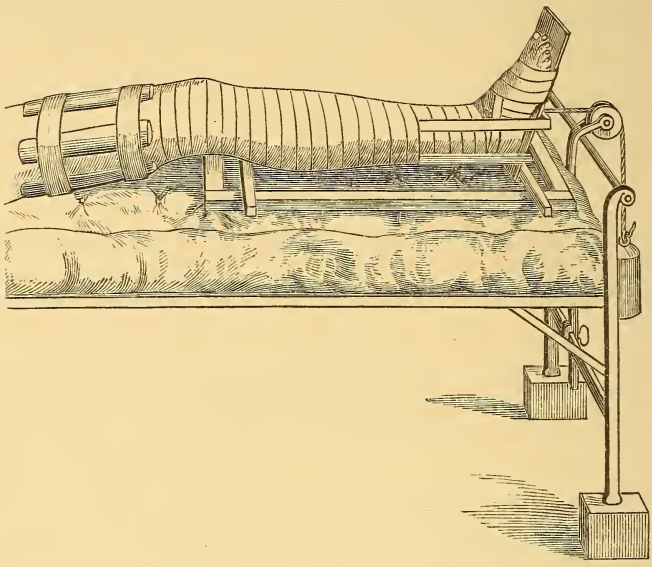
Adhesive plaster applied for extension.

that the plaster should be carried above the knee whenever possible, in order to avoid the prolonged strain upon the ligaments of the joint that is produced when the attachment is to the leg alone, and it is also well to pad the ankles with cotton before applying the roller. Short coaptation splints, usually four in number, or the flexible wooden, Gooch's, splints are strapped upon the thigh, the cord attached to the foot-piece by passing it through the central hole and knotting it on the inside,

carried over a pulley fastened to the foot of the bed, and made fast to the weights. Finally, the foot of the bed is raised six or eight inches, and the leg placed upon a Volkmann's sliding rest.

Volkmann's sliding rest (fig. 112) is composed of a wooden frame, the side bars of which are triangular with an upper edge upon which

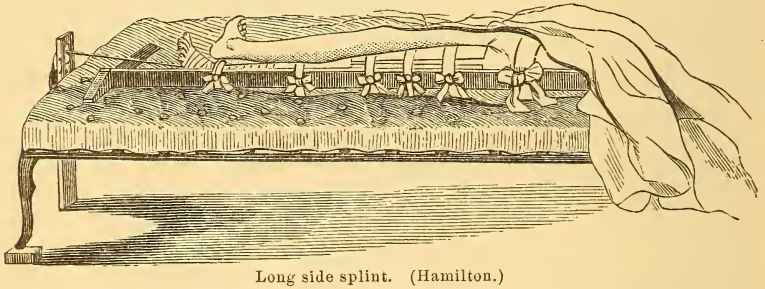
Fig. 112.



Volkmann's sliding rest for fractures of the thigh.

two cross-bars rest. To these cross-bars are fixed a posterior splint and an upright foot-piece, the former cut away centrally in its lower quar-

Fig. 113.

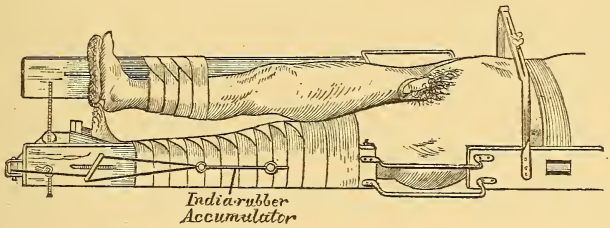


Long side splint. (Hamilton.)

ter to accommodate the heel. The foot and leg are fastened to the splint by a roller bandage, and can thus be moved freely up and down the bed, the cross-bars which support them sliding without much friction upon the triangular side-pieces. This apparatus adds much to the comfort of the patient, and moreover prevents rotation of the leg. It takes the place of the long side-splint and cross-bar (fig. 113).

Elastic extension without a weight and pulley is accomplished by means of stout India-rubber tubing attached to the leg by adhesive plaster as above described and to a long side-splint extending well up toward the axilla. Counter-extension is made by a perineal band fastened to the upper end of the splint, or by a band of stout cloth carefully fitted to the upper portion of the opposite thigh and carried, one end in front, the other behind the body, to the top of the splint, or by a cord attached to the end of a rod extending from the upper end of the splint in front of and well beyond the shoulder, and fastened by bands of adhesive plaster to the abdomen and back, or, finally, by bandaging the other thigh and leg securely to a second side-splint which is attached to the first by a

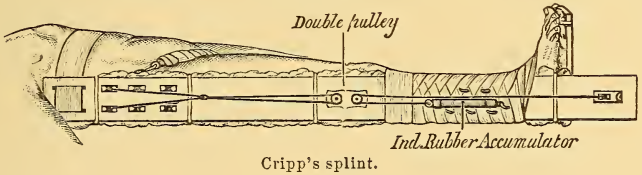
Fig. 114.



Permanent extension by India-rubber.

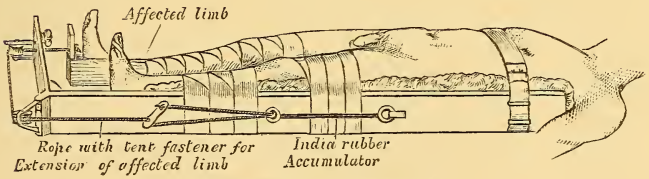
cross-piece at the foot and by a pelvic bandage or brace. Figs. 114, 115, and 116 represent forms in common use. Mr. Bryant prefers the one shown in fig. 114.

Fig. 115.



Cripp's splint.

Fig. 116.



Campbell de Morgan's splint.

The relative merits of, and the special indications for, these different methods of treating simple fractures have, I trust, been sufficently set forth in the preceding pages from the general stand-point to render a detailed comparison and judgment unnecessary at this time. They will be again referred to in connection with the special fractures or conditions to which each may be particularly appropriate.

A plaster dressing that has been applied after complete reduction, and under which all seems to be doing well, may be left unchanged until the expiration of the period usually sufficient for complete consolidation, the length of which varies with the age of the patient and the size of the bone. If, however, it is found to have become so loose by the shrinking of the limb as to afford apparently inadequate support, it should be removed and a new one applied, the opportunity being improved to correct, if possible, any displacement or faulty position that may have occurred under it. Other dressings require a more frequent examination in the later as well as in the earlier periods of the treatment, for displacements, especially the angular ones, may occur as late as the third, or even the fifth week, and then if not promptly detected may soon become irremediable except by operation. In addition to the more thorough examination which is here referred to, one requiring more or less complete removal of the splints, frequent inspection without disturbance is required to detect change of position or the occurrence of any complication. Especial attention must be paid in the treatment of fracture of the upper portion of the leg or of the thigh to the detection and correction of outward rotation of the upper fragment, which is produced by the sinking of that side of the pelvis while the dressing keeps the lower fragment from sharing in the rotation. I have found this tendency very troublesome after excision of the knee, even when the leg and thigh were incased in plaster, and it has been pointed out by Gosselin in fractures of the leg.

The opportunity afforded by a change of the dressing may be improved to communicate gentle movements to contiguous joints that have been immobilized but not involved in the fracture, or to reapply the dressing with the limb in a different position. Opinions are divided upon the propriety of communicating movements to fractured joints, some surgeons preferring to maintain absolute immobility until consolidation is complete, others communicating motion at regular and short intervals after consolidation is well begun, and others, again, using from the first dressings that support but do not immobilize, as a sling in fracture of the elbow. A notable discussion upon this point was raised in 1879 in the Société de Chirurgie by Verneuil, himself an advocate of complete immobilization, and carried on during several sessions. No formal conclusions were reached, but the weight of testimony was in favor of immobility. Verneuil's argument was that the stiffness of a joint is the result of its inflammation, not of its immobility, and that immobility, being the best possible antiphlogistic under the circumstances, would diminish instead of increasing the stiffness. Whatever the surgeon's opinion upon this point may be, it is very certain that he will have to be content with immobilization in many cases, because communicated movements are so painful that patients will not submit to them. He must wait until consolidation is complete, and then try to overcome the adhesions by regular exercise or by breaking them up under anæsthesia.

The same question arises, but is less serious, in the management of large joints adjoining a fracture of the shaft of a long bone. As has been shown, they may be affected by an arthritis due to a concomitant sprain, to extension, or to the spread of the inflammatory process set up

about the fracture, but the severity of this arthritis is seldom great, and its consequences not permanent except in the old and individuals constitutionally predisposed to arthritic troubles. Immobilization may be safely employed for several weeks, and it is exceptional to see a resulting stiffness that does not yield to moderate and natural exercise. It is desirable to hasten its disappearance by daily gentle flexion and extension of the limb as soon as the consolidation is sufficiently advanced to allow this to be done without danger of causing pseudarthrosis, and if the manipulations do not make the joint hot and tender.

In the smaller joints of the hand the case is different. There the extended position and immobility favor stiffening, even when the fracture involves only the forearm or arm, and therefore they should be left free, or dressed in the flexed position and moved every day.

Local measures to prevent or reduce inflammation about a simple fracture are rarely called for, and are generally restricted to some cooling lotion scantily used so as not to wet the permanent dressing, lead and opium, and the ice-bag. The latter must be used cautiously because of the risk of causing local sloughs, or, according to some authors, of retarding the repair of the fracture. The blisters which appear so frequently on the surface of the limb need only to be pricked and protected from chafing by adhesive plaster or flexible collodion.

Medicinal treatment is directed only to the general condition of the patient and guided by such indications as may arise. Phosphate of lime is occasionally given with the idea that it favors the consolidation of the callus by supplying the needed earthy matters, and some cases and experiments have been published as demonstrative of benefit obtained by its use. It is doubtful, however, if it has any such specific action, or any value except as an antacid and absorbent. It is furnished in sufficient quantity in ordinary food, and any excess is rapidly eliminated through the kidneys.[1]

Compound Fractures.

The treatment of compound fractures comprises two indications: the repair of the fracture, and the healing of the wound. The first is met in the same manner as after simple fracture, by reduction and retention, the means employed varying only so far as is necessary to make them compatible with the proper treatment of the wound. It is the latter, of course, which gives this class of fracture its especial importance and dominates the treatment, and which has made compound fractures the type of severe surgical injuries and the basis of statistics collected to determine the merits of contrasted methods of treating wounds.

Fractures may be compound from the beginning, or they may become so by the occurrence of suppuration, the extension of a coexisting wound, or the formation and fall of an eschar. The accepted rule of practice is to treat all fractures with contiguous and possibly connecting wounds as if they were compound, and to avoid explorations of the wound whose sole object would be to determine their communication or non-com-

[1] See Midrin, Thèse de Paris, 1877, No. 96, Du phosphate de chaux dans les fractures.

munication with the fracture. The treatment of eschars due to pressure, contusion, or extravasation should be such as to delay their separation, if possible, until granulations shall have formed upon the broken surfaces of the bone and sealed its canals. Verneuil and Marchand[1] report an interesting case of this character, though not associated with fracture; the skin of the thigh, covering an enormous extravasation of blood coming probably from the ruptured popliteal vein, was contused at several points and showed numerous small gray eschars still adherent to the underlying parts. These eschars were painted twice a day, sometimes with tincture of iodine, sometimes with a solution of perchloride of iron. This treatment delayed their separation until the extravasation had been almost entirely absorbed.

Slight, clean-cut wounds that are capable of healing by primary union, especially such as have been caused by the projection of the sharp end of a fragment, must be treated with the view of favoring this result, and it can often be obtained by simple measures, such as the application of a suture or an occluding dressing. A favorite method of the English surgeons a century ago, and one which is still occasionally employed, is to cover the wound with a pledget of lint soaked in the patient's blood; if all goes well it dries, and the wound heals under it as under a scab. Or strips of muslin, gold-beater's skin, oil-silk, or thin rubber tissue should be dipped in flexible collodion and laid obliquely across the wound, each strip crossing the preceding one at right angles and overlapping about one-third of the preceding parallel one, just as a wound is strapped with adhesive plaster. This is a better method than simply covering the wound with a square piece of the same material dipped in collodion. If serum accumulates under the covering it may be let out through a puncture made with a needle, and the opening closed with another strip.

Simply covering the wound with a few folds of lint soaked in the compound tincture of benzoin is said, by Mr. Fergus M. Brown,[2] to have yielded good results. He recommends it especially for country practitioners, who "are at a loss for some remedy for wounds which will obviate the necessity of going every day long distances to dress trifling injuries." A compound fracture, however, is not a trifling injury.

If the wound is so large or so contused that primary union is not to be hoped for, it should be treated systematically and thoroughly in accordance with the modern principles of the treatment of surgical wounds. First among the various methods by which these principles are carried into practice I place unhesitatingly the Lister method, and next in order the method of "through drainage," introduced by Prof. Markoe, and Guérin's cotton dressing, of which latter, however, my experience is limited to its use after amputations, excisions of joints, and osteotomies.

The wound and the fracture require certain attentions before the dressing is applied. Reduction must, of course, be made as after simple fracture, and this is sometimes made exceptionally difficult by the presence of a complication, the projection of a fragment through the skin.

[1] Dictionnaire Encyclopédique des Sciences Médicales, article, Contusion, p. 150.
[2] Lancet, July, 1880, p. 9.

If extension and counter-extension, aided by pressing the skin upwards or downwards, do not suffice, the wound must be enlarged freely and, if necessary, the muscles divided under it. This, as a rule, is better than cutting off the end of the bone, for the sides of the incision can be brought together again by sutures, and its prompt union may be confidently expected under antiseptic treatment.

The seat of fracture may also be cautiously explored with the finger for the purpose of removing totally detached splinters or foreign bodies. Splinters adherent to the soft parts must not be torn away; it has already been shown (page 121) that they will probably retain their vitality and perform a valuable part in the consolidation that is to follow.

If the tendency to displacement is such that it cannot be successfully opposed by the retentive dressings at command, it may occasionally be desirable to fasten the ends of the fragments together by a suture or ligature. This device[1] finds its most common use in operations for the cure of pseudarthrosis, but it is also occasionally used in fractures of the long bones, and quite recently, in the bold extension which the success of the Lister dressing has given to operative surgery, has been employed even in simple fractures of the patella and olecranon. The most persistent, if not the earliest, advocate of its systematic use appears to have been Lérenger-Féraud,[2] but even he finds it most frequently indicated in cases of delayed union. It does not seem probable that its use at an early period would ever be necessary except in some oblique fractures of the tibia or humerus, marked by a strong tendency to displacement. After having enlarged the wound, if necessary, and exposed the bone the ligature is applied by passing it under the fragments with the aid of a curved, blunt needle or probe, and then twisting it tightly, if of metal, or tying it, if of silk, about them after reduction has been made. The suture is applied by drilling small holes at corresponding points in the fragments, passing a wire or thread through, and fixing it as before. If the fracture is sufficiently oblique the ligature holds the bones more firmly than the suture, and is not liable to cut or break out as the latter is, but its application is likely to require a more extensive denudation of the bone. Another method mentioned by MacCormac[3] is to transfix the bones with a needle and apply the wire in a figure of eight about its ends.

[1] Norris (Am. Journ. Med. Sciences, January, 1842) has been quoted to the effect that Hippocrates practised this in recent fractures, and that Horeau applied the same procedure to ununited fractures in 1805, but the quotation is inexact and incomplete. Norris says Horeau did not originate the idea; it was practised before him by Icart, who bound the fragments closely together by a metallic ligature thrown around them. Dr. J. Kearny Rodgers, of New York, appears to have been the first (1825) to use the suture in ununited fracture of a long bone. Hippocrates only tied the teeth together after fracture of the lower jaw. Bérenger-Féraud (loc. cit. infra), depending upon an incorrect translation of Hippocrates, states that he sutured the bones directly, but the error has been clearly demonstrated by Letenneur in the *Union Médicale*, 1870, p. 949, by the aid of the original text. Littré's translation of the disputed phrase (vol. iv. p. 149) reads as follows: "La coaptation opérée, on attache les dents ensemble, comme plus haut; cela contribuera grandement á l'immobilité, surtout si on sait les attacher régulièrement, nouant les bouts des fils comme ils doivent être noués."

[2] Bull. de l'Académie de Médecine, 1865, vol. xxx.; Gaz. Hebdomadaire, 1867, pp. 610, 624, and 629; and several subsequent papers.

[3] Antiseptic Surgery, 1880, p. 198.

By withdrawing the needle the wire is liberated and can then be easily removed. Some of the other devices used in pseudarthrosis, such as fixation of the fragments by a gimlet, an ivory peg, or an iron nail driven through them, might be also employed in recent fracture.

It is the usual practice to bring out the ends of the wire through the wound and to remove it after the lapse of from two to four weeks by untwisting it and drawing upon one end, for although the wire may, if cut short, become encysted, yet if it should keep up suppuration its removal would then be difficult, or at least more troublesome.

The Antiseptic (Lister) Method.—Mr. MacCormac[1] says: "In no kind of surgical injury have the results accomplished by the antiseptic method been more thoroughly satisfactory and complete than in compound fracture. In future we may expect to save the limb of the patient in all cases in which the extent of damage to the soft parts, vessels and nerves, is not such as to absolutely forbid the attempt. Even in cases where the expectation of saving the limb is not great, we are justified in giving the patient the benefit of the doubt, as we do not endanger his life by so doing; and should gangrene or any necessity for operation occur, we may then amputate without increased risk."

As this asserted superiority is denied by some, and the denial supported by reference to occasional unfavorable results, it seems proper that the details employed by the strong partisans of the method, those who assert its superiority unequivocally as evidenced by the results they obtain, should be fully understood, and I shall therefore give at first the rules laid down by MacCormac and Lucas-Championnière,[2] the latter being the recognized exponent of the theory and practice in France, and then indicate various modifications employed by others.

The materials needed are carbolized gauze,[3] mackintosh or oil-silk, drainage tubes, and two solutions of carbolic acid in water, of the strength of 1 in 40 and 1 in 20. The portion of the limb that is to be enveloped in the dressing is first well washed with soap and water, and then with the stronger solution. An anæsthetic is usually used, because the manipnlations are often painful and protracted.

In cases seen shortly after the receipt of the injury the wound must be thoroughly irrigated with the weaker solution; in those that have been exposed for several hours the strong solution is used. If the external wound is too small to allow complete irrigation, it must be enlarged, for this disinfection of the cavity is asserted to be the most important part of the practice, and one or more counter-openings may need to be made in order that it may be thoroughly well done. For

[1] Antiseptic Surgery, 1880, p. 180.

[2] Chirurgie Antiseptique, 2d ed. Paris, 1880.

[3] If the prepared gauze cannot be obtained it can be made when needed by saturating a loose-meshed cotton fabric (cheese-cloth, for example) with Von Brun's solution and drying it. This solution is:—

Carbolic acid,	100 parts
Castor oil,	80 "
Alcohol or benzine,	2000 "
Resin,	400 "

The resin is first thoroughly dissolved in the alcohol or benzine, and then the others added to it. 100 parts of glycerine may be substituted for the castor oil.

this washing a syringe is used, and when the fracture is not well exposed the liquid should be injected through a soft rubber catheter, the point of which is moved to the different parts of the cavity. When the wound cavity is large and has been exposed for some hours before the treatment is begun, or when foreign bodies have been forced into it, the washing must be continued for fifteen or twenty minutes with the strong solution; or a still stronger one, 1 part of carbolic acid in 5 parts of alcohol, may be used. Attention must be paid to the free escape of the liquid during injection, the cavity must be *irrigated*, not much distended, and the last mentioned solution must be used cautiously and gently, for it is caustic. If suppuration has begun and granulations have formed, the cavity of the wound should be scraped with a curette, or an eight or ten per cent. solution of chloride of zinc may be used first and then followed by the carbolic acid.

In some of the slighter recent cases, as of the leg with perforation of the skin by the end of one fragment, it may be proper to try for primary union, but as a rule drainage tubes should be used, always when the wound is large or unclean, or when the bleeding cannot be completely checked. Counter-openings are made to facilitate the first washing and the subsequent drainage. It is undesirable to pass the drainage tube between the fragments of the bone when this can be avoided, but in the cases in which it has been done it does not seem to have caused necrosis or to have interfered with union.

Loose fragments and foreign bodies are removed, but projecting points of bone should not be cut away unless they actually interfere with the setting of the fracture.

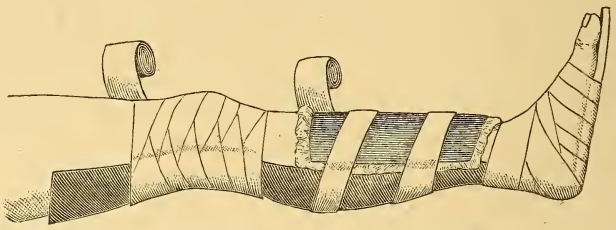
After the disinfection, arrest of bleeding as far as possible, and insertion of the drainage tubes, the incisions are brought together with sutures, pads of gauze or carbolized jute placed to make pressure and prevent burrowing, and the gauze dressing and splints placed over all. The dressing will probably need to be changed the next day and on the third, on account of its saturation with blood or the free serous discharge of the first hours, but afterwards it may usually be left in place for several days. It is seldom desirable to leave the drainage tubes in for more than a week, and as a rule they may be removed whenever the dressing has remained unstained for two days.

I have met with no account of the use of Neuber's bone-drains and permanent dressings in compound fracture, but should think the elastic pressure he recommends would be as useful in these cases as it is after operations.

The most useful form of retentive apparatus in most instances is the plaster splint, so constructed that it can be applied and removed without damage to it, or an interrupted plaster dressing. A fenestrated plaster case does not give sufficient room for the gauze dressing. A convenient form of splint recommended by MacCormac for compound fracture of the leg has been already described in connection with figures 100, 101, and 102. When the wound is on the anterior surface, as it usually is, the posterior splint can be easily arranged so as rarely to require removal. It should be made comparatively narrow, narrower than that shown in figure 100, lined internally with mackintosh or oil-silk, over which

is placed a layer of folded carbolized gauze. This is placed directly upon the leg, the gauze dressing laid upon the wound, and both secured by turns of a roller (fig. 117). The anterior splint is then made and fixed with another roller. When the wound is to be dressed the anterior

Fig. 117.



Compound fracture. Lister dressing and plaster splint.

splint and gauze are removed, the leg remaining undisturbed in the posterior splint, out of which, however, it can be lifted if need be. In like manner, when the wound is on the posterior surface the anterior splint is the permanent one.

In my opinion, the use of the spray is not essential to the success of this method of treating a wound. The irrigation supplies its place at the first dressing, and in the subsequent ones a hand spray may be used, or a sponge saturated with the carbolic solution squeezed over the wound and the mouth of the tube, or a strip of muslin wet with the same solution laid over them. Inability to obtain a steam atomizer is therefore, in my judgment, not a sufficient reason for not resorting to the method.

A device suggested and employed successfully by Verneuil[1] may be used, especially in cases where the wound is small and a drainage tube is not considered necessary. After disinfecting the wound and the adjoining surface he covers it with a piece of oil-silk three or four inches square fastened to the skin on three sides by collodion; the dependent side is left unattached, and the gauze dressings are applied as usual. The blood and secretions of the wound make their way out to the free edge of the oil-silk and are there absorbed by the gauze. When the dressing is changed the oil-silk is not disturbed, its free edge is washed and the new dressing applied. Or if antiseptic gauze is not attainable layers of muslin wet with the carbolic solution and covered with cotton and oil-silk may be substituted. The small square of oil-silk protects the wound from contact with the acid, and healing goes on under it unchecked. It should, however, be painted over with collodion to make it more resisting, or should be double.

"The "*through drainage*" proposed by Prof. Markoe[2] has furnished excellent results. It is based upon the theory that the benefits obtained by the use of carbolic acid are due as much to its topical action upon the tissues as to its power of preventing decomposition. The method has been extensively and successfully employed at the New York

[1] Mémoires de Chirurgie, vol. ii. 1880, p. 271.
[2] Am. Journ. Med. Sciences, April, 1880.

and Bellevue Hospitals during the past year and a half (1881). One or more counter openings are made, perforated drainage tubes passed, and injections of a 2½ per cent. solution of carbolic acid in water made three or four times daily. The wounds are covered usually with a thick layer of antiseptic gauze through which the ends of the tubes project, but this is not considered essential, a simple dressing kept wet with carbolic acid being thought sufficient.

It has been shown, by experiment and clinically, that while the contact of carbolic acid with a granulating surface checks suppuration it also retards cicatrization, and therefore I prefer to follow the example of the pure Listerians and inject the wound only when there is a definite reason for so doing, such as putrefaction, excessive suppuration, or inflammation. Still, Prof. Markoe has observed in several cases that the injections relieved pain or soreness so markedly that the patients asked to have them repeated more frequently. I have heard it charged that necrosis was more likely to occur under this than under the Lister treatment, but have never observed any facts that substantiated the charge. I have used it a number of times in old fractures with large freely suppurating cavities and inflamed borders, and in some severe recent ones with much oozing, and have always been satisfied with the results. I recall one case in particular, a severe compound fracture of the lower third of the leg with a projecting fragment and large lacerated wound. It was first seen upon the fourth or fifth day when the patient presented a most unpromising outlook, with sub-delirium, a dry tongue, and a temperature of 104°; the limb was much swollen, the wound fetid, and its edges inflamed and boggy for a considerable distance. Drainage tubes were passed to either side of the leg and frequent injections made. The temperature fell, the wound improved rapidly, and the patient recovered without necrosis, although for some time the end of the upper fragment was exposed and bare for more than an inch.

Guérin's cotton dressing, which grew rapidly into favor in France in 1871 in the treatment of amputations and excisions, has been used successfully, although more sparingly, in compound fractures. So far as can be judged from current publications it now holds a place second to the antiseptic method in French hospital practice. The method consists essentially in the envelopment of the limb in very thick layers of cotton batting tightly bound on with a roller bandage and left in place for three weeks. The principal objection to it in the treatment of fractures is the difficulty of securing at the same time efficient contention of the fragment. This, however, is of secondary importance when the lesions are very grave and the question of amputation is impending; under such conditions the surgeon may be well content to save the limb even if its form should be more or less irregular, and, in default of better means, the cotton dressing enables him to do this. The thermometer may be safely depended upon to give timely notice of complications occurring about the wound.

The limb and the wound are first disinfected; then the entire limb is wrapped in successive layers of cotton batting, the thickness of which when tightly compressed with a roller bandage is about two inches; reduction is made by extension and counter-extension, and immobility

secured by a gypsum, starch, or silicate of soda bandage applied over all. Guérin advises that the uniformity of the compression should be further assured by the application of a second roller bandage on the second day, and if this is done it must of course precede the hardening bandage.

Verneuil[1] uses a modified form of this dressing which, he claims, assures a better retention and gives an opportunity for inspection of the parts without disturbing the patient. It consists of a Scultetus apparatus with the addition of an inner layer of broad bands of cotton batting corresponding in direction and mode of application to the layer of short bands. (See p. 160.) The thickness of the layer is very much less than that of the Guérin dressing, but, according to Verneuil, its efficiency is as great. He further covers the wound with a patch of oil-silk as above described, and lays over it compresses wet with carbolized water.

The inflammatory processes that may supervene in the progress of the case are met in accordance with the general principles of surgery. Pus that has burrowed or formed at a distance must be promptly evacuated; it is not necessary to wait for fluctuation when the bogginess and tenderness at any point show so clearly what is going on underneath, or when a probe can be passed down to the collection through the main wound. These abscesses usually communicate with the main cavity, and it is desirable that drainage tubes should be passed through from one to the other.

Inflammation about the wound is best controlled, in my experience, by the free use of the weaker carbolic solution in frequent injections and upon compresses. In fractures of the fingers, hand, or forearm, with severe inflammation of the inter-muscular spaces of the latter, I have seen much good result from immersion of the limb for several hours in a bath of tepid water containing one per cent. of carbolic acid. I usually keep it in the bath during the greater part of the day, covering it in the intervals and at night with compresses wet with the two and a half per cent. solution, and continuing this until the inflammation subsides.

Prof. Hamilton recommends the use of compresses of sheet lint kept constantly wet with water at the temperature of 95° to 100°, or, in the case of gangrene, actual or impending, 105° to 110°.

The use of cold, either by the ice-bag or irrigation, has been recommended, but the weight of evidence is now against it. Spillmann[2] says it is actually harmful in fractures of the arm or thigh, often useful in those of the forearm or leg, and "yields marvellous results when applied to injuries of the hand or foot." Used upon a badly contused wound it will almost certainly cause gangrene In such cases a light well-made poultice may sometimes be used with advantage.

If suppuration is prolonged it may be profuse and undermine the patient's strength to such a degree as to render the sacrifice of the limb necessary to the preservation of his life; or it may be slight, the wound being reduced to a simple sinus, and the fracture so well consolidated as to make the limb useful. Both results are more rare than they were

[1] Loc cit., p. 272.
[2] Dict. Encyclopedique, 4th Series, vol. iv. p. 169.

formerly. Sinuses are kept up by caries, necrosis of portions of the callus or of splinters, and by foreign bodies introduced at the time the fracture was received. When due to caries they may sometimes be cured by stimulating injections such as the sulphate of copper or of zinc, or Villate's liquid. When due to necrosis or the presence of foreign bodies they must be enlarged and the cause removed. This may require the cutting away of a portion of the callus, and it should be done thoroughly. The antiseptic method has furnished some rapid and complete cures in this class of cases.

For the treatment of other complications the reader is referred to the preceding chapter.

The same principles and details of treatment, modified somewhat by the different anatomical conditions, are applicable to the treatment of *compound fractures communicating with or involving a large joint.* The antiseptic method has wrought an even greater change in the treatment of this variety than in the less complicated ones of the shaft, and it is now the rule to save the limb where formerly it was the exception. The opening into the joint must be enlarged if necessary, or free incisions made to insure thorough disinfection and drainage; this seems to be the capital point in the treatment, for if the case does well it does well from the very first, from the moment of the primary cleansing. In fractures of the upper extremity with much shattering, the broken surfaces of the bone may advantageously be made regular by a formal excision, because mobility rather than solidity is sought for; while in the lower limb under similar circumstances as much of the bone should be preserved as is possible, in order that the support may be solid even if the mobility is lost. Ollier[1] has pointed out clearly the change effected by the antiseptic method in the indications for resection after compound fractures of joints in consequence of their diminished gravity when treated conservatively under the Lister dressing. The surgeon can advantageously wait in doubtful cases, as Von Langenbeck[2] also showed by his analysis of the results obtained after gunshot wounds of joints, until the parts shall have shown the limit of their ability to repair their injuries unaided, and then, if necessary, amputation or secondary resection can be undertaken. The experience of both these surgeons has shown that the applicability of partial excisions is greater than has been supposed, of excisions, that is, in which only a portion of the articular surface is removed, whether it be the entire end of one of the members or contiguous portions of both. Instead of a formal excision,—that is, of an operation consisting in the removal of all free or fissured splinters and the regularization of the ends of the bone,—Ollier limits his interference to the removal of foreign bodies and completely detached splinters, leaving those that are still adherent to the periosteum, even if only partially so. The death of a splinter is due not so much to the traumatism as to the subsequent inflammation and suppuration. If these are avoided the splinter preserves its vitality as after simple fracture. The main condition of success is

[1] Résections et pansements antiseptiques, in Revue Mensuelle de Méd. and Chir., 1880 pp. 926 and 931.

[2] Archiv für Klinische Chirurgie, 1874, vol. xvi.

that the cavity, and in this term are included all the pouches of the synovial sac, shall be efficiently drained, and therefore Ollier multiplies his counter-openings and drains, and diminishes the number of his sutures.

Mr. Lister's practice, according to Cheyne,[1] is to enlarge the opening freely when it communicates directly with the joint, and to wash out the cavity with the 1 in 20 carbolic solution if the wound is seen within an hour or two of its receipt, or with the 1 in 5 alcoholic solution if a longer time has elapsed, using a gum catheter in order to reach all its recesses. If the communication with the joint is through a fissure in the bone, as in fracture of the lower third of the femur with splitting of the condyles, he makes a separate incision into the joint at a point suitable for drainage, washes it out, and inserts a drainage-tube at each opening.

Gunshot fractures owe their special gravity to the shattering of the bone and the contusion of the soft parts, conditions which render suppuration inevitable, and increase the probability of the occurrence of severe osteomyelitis. The necessity for the rigorous employment of the antiseptic method is therefore all the greater, and experience has shown that its results are favorable. Some of these results have been already quoted in Chapter II., together with the choice of operation in the injuries of the different limbs. Sufficient experience, perhaps, has not yet been accumulated to show how far conservative treatment may be safely carried, but the facts collected from the Holstein, Austrian, and Franco-German wars, and so carefully analyzed by Von Langenbeck, and the scattered reports of some army surgeons after the more recent wars, prove that in gunshot as in other compound fractures an attempt to preserve the limb may be made under antiseptic precautions, without increasing the risk to the patient's life, if prompt recourse is had to secondary amputation or excision when the indications for them appear. It seems not unlikely that when the bone is covered by thick layers of muscle, as in the thigh, Prof. Markoe's method of "through drainage" with frequent injections would be especially useful in the first week by promptly removing the gangrenous shreds cast off from the sides of the wound, and by assuring an asepticity which, perhaps, could not be obtained by a single irrigation at the first dressing.

Immediate amputation after compound fracture is indicated when there exist in addition injuries to the main bloodvessels which make the preservation of the limb impossible, or to the nerves which would render it useless, or to the soft parts so extensive, or in such positions, that the cicatrix would create a disability greater than that of the loss of the limb, or when the bone is literally smashed over a great extent and the neighboring joints are involved.

Secondary amputation finds its indications in profuse and prolonged suppuration that cannot be checked and that endangers the patient's life, or after a failure to keep the wound aseptic and the consequent destruction of parts which it had been thought possible to save, or in similar conditions in articular fractures when excision is contra-indicated.

There will always be cases in which the greatest uncertainty and anxious doubt will be felt by the surgeon, and this doubt is by no means

[1] British Med. Journal, Nov. 29, 1879, p. 859.

greatest in those whose experience is the least extensive, since a single failure may leave a painful impression, or have a weight that many successes cannot remove, or entirely overcome. But, in consideration of its importance, I may repeat that we have in the antiseptic method a means of safely postponing the decision in these doubtful cases, of giving the patient the chance, and waiting until he has shown his ability or his inability to profit by it.

If amputation is considered necessary immediately after the accident it should be performed without delay, for all are agreed that the dangers of the operation are increased by the necessity of cutting through the inflamed tissues of a feverish patient. Experience has also shown that, the period for immediate amputation having passed, it is better to wait until suppuration has become fairly established and the general reaction and acute inflammatory condition of the parts have subsided. But this is not to be taken as a fixed and inflexible rule, for many surgeons hold, and with apparent reason, that although the results of late, secondary, amputation are statistically better than those of amputation performed during the acute inflammatory period, yet many patients whose operations are postponed succumb before the period considered fit for the operation has been reached, and this mortality should be added to that of the secondary amputations in making the comparison. Instances are not lacking in which amputation, under conditions which made the preservation of the patient's life in either case apparently hopeless, has resulted successfully.

In conclusion, I may quote some of the sentences with which a surgeon[1] of large experience terminates his consideration of this subject. "This question," he says, "of the propriety of amputation is one of the most difficult which the surgeon has to solve, and it is impossible to state categorically what cases need it, and what cases can recover without it. In doubtful cases I lean always towards preservation of the limb, and while recognizing that primary amputations are less dangerous than secondary ones, I prefer to take the chance of saving the limb. But when it becomes clear that all hope of doing this is lost, I do not allow myself to be stopped by the gravity of the situation. . . . . I believe one is justified in amputating so long as purulent infection (pyæmia) has not actually taken place. The cases quoted, and the number could be increased, prove this sufficiently. . . . Finally, we may be called upon to amputate to protect the patient from the consequences of suppuration and hectic fever. At what period should the decision be made? Upon this point I can say nothing positive. Each case presents special indications. The only recommendation I can offer is not to wait until the patient is completely exhausted by the suppuration."

I append also a few of the late Prof. Cowling's "Aphorisms on Fractures" because they present the ideas in a compact and easily remembered form:—

"With the improved methods of treatment the danger to life and limb in compound fracture has been reduced to such an extent that former laws for determining the question of amputation are to be recast."

[1] Valette, in the Dict. de Méd. et Chir. Pratiques, article, Fracture, p. 502.

"The best time to dress any fracture is immediately after its occurrence."

"Temporary dressings are only to be used when the materials for permanent dressings are not to be obtained, or for the purpose of moving the patient."

"The indications for treatment of fracture are, first, reduction of the fragments of bone, second, their immobilization."

"Perfect immobilization is only to be obtained when the joints contiguous to the fracture are secured; and there is no law more important than this in fractures of the lower extremity."

"One of the commonest reasons for the failure and disaster in the treatment of fracture arises from the fact that bone and muscle only are considered, and bloodvessels and nerves are left out of sight."

"Carved and manufactured splints generally fit nobody, and are to be rejected as not only expensive but damaging. Deal board, pasteboard, and the materials for the plastic apparatus form all the appliances needed by the surgeon."

"The application of a bandage immediately to the skin, whether as a protection or to prevent muscular spasm, has resulted in such disaster, that it is one of the curiosities of surgery how it could be repeated at this day. When cotton is placed *over* such a bandage it forms an absurdity scarcely credible in a man of ordinary sense."

"Comfort is the sign that a fracture has been properly dressed. . . The general law is that pain should speedily subside when the dressings are not at fault."

"Frequent dressings of fractures for the purpose of examination are not only useless but hurtful."

"Whenever it is possible, after the dressing of a fracture, it should be seen again in a few hours, and the case should receive daily attention in its earlier stages."

"The surgeon is to regard not only the welfare of his patient, but his own reputation. To this end he ought to give fair warning of possible ill results. . . . There is one thing which the law is slow to excuse —neglect."

CHAPTER IX.

PSEUDARTHROSIS AND DELAYED UNION.

In a relatively small number of fractures of the shaft of long bones it is found on examination of the limb at the expiration of the period which is usually sufficient for the completion of repair that the fragments are still movable upon each other. The degree of this mobility and the length of time during which it persists are variable. When it is slight and but a few weeks or months have elapsed since the injury was received, it is usually spoken of as *delayed union;* when more free and painless, and when several months have passed the condition is described as a pseudarthrosis. The distinction has an important practical value, for it has much weight in determining the choice of a method of treatment; union that is simply delayed will often become complete, that is, the existing soft callus will complete its natural evolution by ossifying, by the aid merely of a dressing that immobilizes the parts, while a pseudarthrosis can be overcome only by operative measures of greater or less severity.

Delayed union that does not terminate in pseudarthrosis causes but little inconvenience beyond the prolongation of the treatment, but pseudarthrosis may result in a disability so complete that amputation of the limb is sought as an amelioration. This is rare, and is found only in the lower extremity; pseudarthrosis of either the arm or forearm can be sufficiently controlled by mechanical appliances to enable the patient to make good use of the limb, and even in some cases the abnormal mobility is so slight that no additional support is needed.

Fibrous union of a fractured short spongy bone or the expanded extremity of a long one, or between an apophysis and the bone from which it has been torn is not usually spoken of as pseudarthrosis, and, as has been elsewhere shown, is a common result after fracture of the patella and of apophyses to which powerful muscles are attached.

Norris,[1] who wrote the first elaborate article upon this subject, one that has served largely as the basis of most subsequent ones, described four varieties of incomplete union, which, however, if differences in degree are disregarded, may be reduced to two: 1st, those in which a more or less extensive fibrous band, with or without nodules of bone developed in it or on the surface of the fragments, unites the latter; 2d, those in which an actual joint with a capsule and cartilaginous surfaces is formed by the broken ends. The second form is rare; the first is the common one and presents several important differences in degree. Thus, the ends of the bone may be in good position and enveloped in a

[1] Am. Journal Med. Sciences, 1842, vol. xxix. p. 13.

large callus which lacks only ossification to make the union perfect. It is an arrest of the normal process of repair at a comparatively late period, may be recognized by the presence of the callus and the pain caused in it by communicated movements, and is amenable to treatment by simple methods which favor or excite ossification. Or the union may consist of a longer or shorter, more or less voluminous bundle of fibrous tissue uniting the bones end to end when they have been kept in position, or laterally when they have over-ridden. The ends of the bones are altered by a formative or rarefying osteitis which produces in the one case closure of the medullary canal by a bony deposit, and nodules upon the surface, in the other the absorption of prominent points and angles, and the reduction of the ends to conical points. In a remarkable and exceptional case quoted by Norris from the *Boston Medical and Surgical Journal*, July 11th, 1838, p. 368, a lad, 18 years old, broke his right humerus near its middle; while repair was apparently progressing favorably he fell and again broke the arm at the same place. This time the fragments not only failed to unite but disappeared gradually by absorption until all the bone between the shoulder and the elbow had disappeared. When last seen, eighteen years later, the arm hung loose from the shoulder and could be twisted twice completely around without pain. On traction it would extend to a length equal to that of the other, and then if released would immediately shorten about six inches.[1] Agnew[2] refers to a case under his own observation in which half the humerus had disappeared in eight years after fracture. Gurlt quotes a somewhat similar case reported by Peacock.[3] A lad, 18 years old, had a pseudarthrosis of the femur that had lasted ten months and was then treated unsuccessfully by resection. Three months later the limb was amputated on account of prolonged suppuration and hectic fever. It showed serous infiltration of the connective tissue, marked atrophy of the muscles and especially of the bone which consisted of little more than a shell one-tenth of an inch thick at the thickest part. The lower fragment was even thinner, and where the two fragments were in contact the spongy tissue had been entirely absorbed. The atrophy involved the entire lower end of the bone, which could be easily cut with a knife. The tibia, fibula, and bones of the foot were softened, and their compact tissue had been in part replaced by marrow.

The mobility in these cases of fibrous union depends upon the length, number, and position of the connecting bands. When the fragments override for a considerable distance, as in a fine specimen of ununited fracture of the upper third of the femur, which is preserved in the Bellevue Hospital Museum and was taken from a patient at one time under my care, and are supported by contact with, and fibrous attachments to, bony prominences the mobility will be very slight and the limb, perhaps, useful; when, on the other hand, they are end to end and the union consists only of slight fibrous bands, or even of merely a fibrous thickening of the adjoining muscular layers, the mobility may be very free.

[1] The man died at the age of 70, and the report of the autopsy is given in the Boston Med. and Surg. Journal, October 10th, 1872.

[2] Surgery, vol. i. p. 746.

[3] London Med. Gazette, 1838–39, vol. ii. p. 847.

In the other form an actual joint is formed, the ends of the bones are more or less enlarged by new deposits, rounded and smooth, and covered entirely or in part by cartilage. They are united by a complete peripheral capsule and moistened by a liquid resembling synovia. The portions of the contiguous surfaces not covered by cartilage are eburnated and made smooth by friction upon each other. Although I have met with no recorded case in which it is distinctly stated that the cartilaginous character of the tissue covering the ends of the bones was determined by microscopical examination, and although it is known that wounded cartilage repairs itself usually by fibrous tissue, yet I believe the tissue to be real cartilage, in some cases at least, because it has been demonstrated to be so in one case[1] of false joint established intentionally by operation, and because, as we have seen, the callus is cartilaginous during one period of its development. It seems justifiable to assume that portions of this cartilaginous callus may persist and remain as articular cartilage just as portions remain in the normal embryonal formation of bones and joints. An additional point of resemblance to normal joints is found in the loose cartilages which are occasionally found within these joints of new formation. A specimen of this kind is pictured in the first volume of Holmes's System of Surgery. Gurlt[2] collected five cases of this form of pseudarthrosis in the arm, three in the forearm, and two in the thigh, verified by post-mortem examination.

Pseudarthrosis is not easily produced intentionally in animals, but Breschet succeeded in obtaining six specimens which showed distinct cavities with capsular ligaments and synovial liquid. The synovia appeared at the latest on the twenty-seventh day, and the older the fracture the more had the walls of the cavity lost their pink color, and become smooth and polished on the inside, and showed externally the appearance of fibro-cartilage. The capsule surrounded the broken ends and was continuous with them. In some cases he found the broken surface of an opaque, white color, glistening like synovial membrane, and covered by tissue resembling articular cartilage. A period of eighty-five days was sufficient for the production of this condition in a dog.

The different statistics and estimates that have been published concerning the frequency of failure of union as compared with the total number of fractures vary within wide limits, but all agree in making it small. The following are taken from Norris, Gurlt, and Agnew: Pierson found only 1 case in 367 fractures treated in the Massachusetts General Hospital; Lonsdale only 5 or 6 in 4000 fractures treated in the Middlesex Hospital in London; Stanley remembered none in sixteen years at St. Bartholomew's Hospital in London, and Mr. Callender[3] says that in the seven years ending in 1867 there had been treated in the same hospital 2376 fractures, exclusive of those of the upper extremities, and "with the exception of certain fractures of the patella and neck of the thigh bone there had been but one case of non-union." There was none in 946 cases of fracture treated in the Pennsylvania

[1] Sayre's Orthopedic Surgery, 1876, p. 442.
[2] Loc. cit., p. 592.
[3] Med. Chir. Trans., vol. li. p. 148.

Hospital between 1830 and 1839, and Agnew says he could learn of none among the 6480 fractures treated in the same hospital between 1850 and 1874. Amesbury alone speaks of it as "by no means uncommon," and places his personal experience at 56 cases. The conclusion to be drawn is that it is exceptionally rare under proper treatment, and that when it occurs under such circumstances it is generally due to a definite, recognizable cause independent of the treatment.

The cases contained in the tables of Norris, Gurlt, and Agnew are divided as follows among the different bones:—

	Norris (1842).		Gurlt (1861).		Agnew (1878).	
Femur	48	32 per ct.	132	27 per ct.	155	24 per ct.
Leg (one or both bones)	33	22 "	131	27 "	180	28 "
Humerus	48	32 "	165	34 "	219	34 "
Forearm (one or both bones)	19	12 "	50	10 "	76	12 "
	148		478		630	

I presume that all of Norris's cases are included in both the other lists, and probably most, if not all, of Gurlt's are included in Agnew's, therefore the three lists cannot be added together to make a grand total. Furthermore, these figures do not represent an equal number of cases, for many of the cases appear several times in each list under the different methods of treatment. It will be noticed that the percentages of Gurlt's and Agnew's correspond very closely, and that in them the pseudarthroses of the humerus are the most numerous, and those of the forearm the fewest. By reference to the general statistics given in Chapter I. it may be seen that fractures of the humerus are relatively few when compared with those of the other large bones of the extremities, and consequently the percentage of the cases in which union fails after fracture of the humerus is much greater, even in comparison to others, than the above lists indicate when taken alone. Agnew's list contains 37 cases of non-union of both bones of the forearm, 23 of the radius alone, and 16 of the ulna alone; 94 of both bones of the leg, 84 of the tibia alone, and only 2 of the fibula.

Gurlt's analysis shows the same preponderance of pseudarthrosis as of fracture in males, and the greatest frequency of both between the ages of 20 and 30 years; but, on the other hand, an important difference in childhood. While his general statistics show that fractures are almost as frequent in the first ten years of life as they are in the third decade, during which they are more frequent than in any other, the proportion of pseudarthrosis in the same periods is only as 1 to 8. This rarity of non-union in childhood is doubtless due to the vigor of the healing process at that age. His statistics show further, in contradiction of a rather widely held opinion, that advanced age is not unfavorable to repair, and that, all things considered, non-union is more common in the prime of life than at any other period. Norris claimed, on the strength of recorded observations and daily experience, that advanced age was not to be considered among the causes of non-union, and quotes some cases in which union took place within the usual time in very old patients.

The causes of delay or failure of union are general and local, those which lie in a constitutional vice or temporary deterioration of the condition of the patient, and those which lie in the fracture itself or the associated injuries. These causes may act simultaneously or separately, and, as may be inferred from what has been said concerning the rarity of this result, are by no means certain to produce it in any given case in which they may be operative. The repair of a fracture requires a special productive effort on the part of the injured tissues, and, as is seen occasionally after injury of other parts, the resources of the organism are sometimes insufficient to meet the demands made upon them; the local causes are usually mechanical.

The general causes to which the occurrence of pseudarthrosis has been attributed in different cases are tabulated by Gurlt, who follows Norris in this quite closely, as follows:—

1. Syphilis.
2. Pregnancy.
3. Physical deterioration.
   a. Due to a drain upon the system (hemorrhages, lactation).
   b. Due to general debility (especially from insufficient nourishment).
4. Advanced age.
5. Severe acute diseases (typhoid fever, variola, etc.).

Of each of these except the fourth he quotes a few instances, but couples them with others to show that the influence is a slight one. Of the fourth he quotes only cases to show that prompt union is possible in very old people, and refers to the statistics already given to prove that the frequency of non-union is not disproportionately large in old age.

Of the local causes the same may be said as has just been said concerning the general ones; any one may prevent or delay union, but none will certainly do so. Some act mechanically, some by change in the blood or nerve-supply of the parts, others by modifying the productive process either directly by disease in the broken ends of the bones, or indirectly by inflammation of the surface of the limb. They may be divided as follows for detailed consideration:—

1. Unfavorable relations or conditions of the fractured parts.
2. Interposition of a foreign body.
3. Defective innervation.
4. Defective blood-supply.
5. Disease of the bone.
6. Inflammation on the surface.
7. Defective treatment.

1. The unfavorable relations or conditions of the fractured parts consist in separation of the broken surfaces by over-riding or extreme lateral displacement of the fragments, and loss of substance by splintering, resection, or necrosis. Lack of contact between the broken surfaces is the most frequent cause of non-union, and it is observed not only when the ends of the fragments are separated longitudinally, but also when the line of fracture is oblique and one of the fragments has the constant tendency to lateral displacement which has been mentioned elsewhere as common in some fractures of the tibia. Not only does the actual

separation act unfavorably, but the mobility, which alone allows the separation to take place after reduction has been made, adds another obstacle to union. Loss of substance due to partial necrosis of one or both fragments is less likely to cause non-union than loss of substance due to comminution or resection, because in the former case the periosteum of the necrosed portion is more likely to preserve its position and to be stimulated to produce rapidly a shell of new bone to take the place of the sequestrum as soon as the latter is removed.

2. Foreign bodies introduced from without, such as bullets or portions of the tissues of the limb, splinters, muscles, or tendons, and possibly even blood-clots may delay or prevent union by occupying the space which would otherwise be filled by the callus. Splinters of bone, as we have seen, usually preserve their vitality, or, even if dead, may become firmly imbedded in the callus, and serve to strengthen the union in simple fractures. In compound fractures which suppurate they may die and then act like a foreign body introduced from without. Portions of muscle are liable to become interposed only in fractures accompanied by considerable displacement and laceration of the soft parts, and when, the fracture being very oblique, the sharp end of one fragment has been driven into the muscle and has not been withdrawn. Gurlt thinks this complication is probably comparatively common, and is the cause of many of the slight delays noticed in consolidation. The examination of various specimens has shown that muscular bundles thus interposed atrophy by disuse or pressure, and may disappear entirely. Collections of blood are thought by some to act in a similar manner, but the study of the normal process of repair and clinical observation of some cases of fracture complicated by traumatic aneurism indicate that the obstacle thus created must, if it exists at all, be very slight. Granulations penetrate a soft clot very readily, and hasten its absorption, and it is even claimed in some quarters, although improperly in my opinion, that the clot is capable of producing new tissue within itself, and without extraneous aid. The observations which have led to this belief show at least that the clot is not an obstacle to repair, either of soft parts or of bone.

3. Defective innervation. It has been repeatedly asserted and denied, and both opinions supported by the citation of cases, that injury to the nerves supplying a fractured limb or to the spinal cord above the origin of such nerves impedes or entirely prevents the formation of a callus. The disagreement appears to have arisen through a failure to discriminate between the paralyses in the different cases, and the same error has affected many of the experiments made to elucidate the question. A recent thesis by Bognaud,[1] presents the facts very clearly, and shows by clinical and experimental observations that certain portions of the nervous system do exercise a trophic influence upon the bones as upon other tissues, and that the destruction of the nerves through which this influence is conveyed, or of the centres at which it arises, prevents or retards consolidation. The most frequent examples are furnished by fractures of the lower extremity with concomitant injury to the spinal

[1] Sur l'Influence de quelques lésions du système nerveux sur la formation du cal. Thèse de Paris, 1878, No. 370.

cord. In paralysis due to a lesion limited to the upper portion of the cord, the lower segment remaining intact, repair is not interfered with, but on the contrary, is rather aided by the immobility and insensibility produced by the paralysis. The explanation is found in the supposed existence of trophic centres in the lower portion of the cord, from which trophic nerves pass in company with the others to be distributed to the lower limb.

Bognaud collected six cases of fracture of the leg, or of the fibula alone, with complete paraplegia due to simultaneous fracture of the vertebral column at or below the last dorsal vertebra, in which consolidation failed entirely to take place; and he gives others in which, the paralysis being incomplete, or the lesion of the spine situated at a higher point, partial or complete repair followed. He reports also in full a case which came under his own observation of fracture of the humerus in a healthy man of 24 years, due to a fall which occasioned also paralysis of all the muscles of the same arm, except the deltoid, and almost complete loss of sensibility in the limb. Three and a half months afterwards, when the record ends, there was not the slightest trace of union of the broken bone. The fracture had been judiciously treated in hospital, and during the last month and a half electricity, first by the interrupted and then by the continuous current, had been employed in vain by Broca.

4. Defective blood supply, the result either of occlusion of the principal artery of the limb, or, more especially, of the relations of the nutrient artery of the bone to the fracture, has been considered a cause of non-union. The only case mentioned by the authors, in which repair seems to have been retarded by occlusion of the main artery of the limb is one reported by Dupuytren,[1] a fracture of the leg in a woman aged 62, whose femoral artery he had tied on account of a traumatic aneurism caused by the fracture. Consolidation had scarcely begun at the end of the first month, and was not complete until after the expiration of four months. On the other hand, there are a number of cases recorded in which a similar operation caused no delay, and from our knowledge of the rapidity with which the collateral circulation is established, there seems no reason to suppose that the ligature of the main artery can have any material influence upon the consolidation.

A similar conclusion must be reached regarding the influence of the nutrient artery. Guéretin, and subsequently Norris, collected some statistics designed to show the position of the ununited fracture with reference to the point of entrance and the direction of the nutrient artery. The results were conflicting. Guéretin collected 35 cases of ununited fracture, in only 10 of which the injury was situated in the portion of the bone towards which the artery was directed; Norris collected 41 cases, in 27 of which the injury occupied that portion. Taken together the two lists give 76 cases with 37 fractures on one side of the point of entrance of the artery, and 39 on the other.

The statistics themselves are untrustworthy, as Norris admits, because the observations were not controlled by dissection, and the point at which the artery enters the bone varies widely. Curling thought he found

[1] Quoted by Malgaigne, loc. cit., vol. i. p. 144.

corroborative evidence of the correctness of the claim in an alleged partial atrophy, after fracture, of the fragment towards which the artery was not directed, but Gurlt, who afterwards examined his specimens, declared himself unable to recognize any difference between the two parts. As the soft parts, and especially the periosteum, take a much more prominent part in the formation of the callus than the bone itself does, and as their blood-supply is not received through the nutrient artery, and as we have learned that even total separation of a splinter does not necessarily cause its death, the theoretical support of the assertion is no stronger than that supplied by observation, and it must be dismissed as entirely unproven and improbable. Indeed, an argument based upon a supposed inequality in the blood-supply due to the direction of the nutrient artery would justify equally well a conclusion directly opposed to the one reached by these writers, for, if the amount of the blood supplied to a bone through its marrow varied in the different parts according to the direction of the nutrient artery the half which received the less amount in this manner would, theoretically, have to receive a relatively larger amount through the vessels of the periosteum in order to make good the difference, and, thus receiving a larger amount from its surface, and less through its central canal, would be less affected by a fracture which cut off the latter supply.

5. Disease of the bone. Any of the diseases which have been mentioned as possible factors in the etiology of the so-called spontaneous fractures, syphilis, cancer, hydatid or other cysts, may interfere in like manner to delay or prevent consolidation. Gurlt's table contains four such cases, two of hydatids and two of syphilitic exostoses. The commonest cause of this kind, however, is suppuration of the bone maintained by a splinter or a necrosed fragment. The influence exerted by the presence of such a body may delay consolidation until its removal, or may lead to the absorption of a callus already formed and perhaps even sufficient to unite the fragments firmly. The removal of the splinter or of the sequestrum is usually followed by complete recovery, but in some cases permanent pseudarthrosis has resulted. Gurlt quotes the following interesting case from Gerdy.[1] In a man whose right arm had been broken by a gunshot nine years before and had slowly united, an abscess formed at the site of the fracture, was opened, and gave exit to several small fragments of bone. It failed to close, the callus softened, and notwithstanding proper treatment the bones failed to reunite ; the patient became hectic, and the limb was amputated. The bone was found distinctly inflamed, spongy, and traversed by vessels. The marrow was slate-colored in places, red in others, and suppurating at the points corresponding to the wound.

6. Inflammation on the surface of the limb. Malgaigne[2] says that phlegmons and erysipelas occurring in a fractured limb generally retard the solidification of the callus, and he quotes a case that came under his own observation of a man who had broken one of his fingers ; a phleg-

[1] Chirurgie pratique, 3me Monographie, Maladies des organes du Mouvement, Paris, 1855, 8, p. 126.

[2] Loc. cit., p. 144.

monous inflammation was set up in the neighborhood of the fracture, the callus did not begin to form until after this had subsided, and consolidation was not complete until after two and a half months had elapsed.

7. Defective treatment. This includes errors of commission and omission. Among the former is reckoned the prolonged use of cold applications, and there is every reason to believe that when cold is used in its most active and efficient forms, such as bags of cracked ice or irrigation through a coil of lead tubing, upon limbs that are not acutely inflamed the consolidation of a fracture may be considerably delayed thereby. Malgaigne goes much further and accepts the theory, which he traces back to the times of Paulus Aegineta and Avicenna, that moist applications, hot as well as cold, are injurious. The same charge has been made against the method of continuous irrigation of a wound, and in the statistics of nine compound fractures treated in this manner collected by Nivet[1] it appears that only two consolidated within the usual time, four required from two and a half to seven months, one was dismissed uncured after more than six months of treatment, and two died. Gurlt urges, very properly as it seems to me, that there are so many other factors involved in these cases that it is difficult to draw any positive conclusions concerning the influence of the treatment in causing the delay of the consolidation.

Soon after the introduction of the immovable dressing in the treatment of fractures, the charge was made that it favored non-union or delay of union, especially if applied immediately after the accident. Malgaigne pointed out that the cause in the cases cited was not the early application of the dressing but possibly its too tight application, and the correctness of this explanation has been amply demonstrated clinically and experimentally. Malgaigne was at a loss to reconcile some of the facts with the theory of too great compression and sought an additional cause in the prolonged withdrawal of the limb from the light and air, a circumstance to which attention had first been called by Cloquet as the cause of the changes occasionally observed in those times and known as local scurvy. The picture drawn by Cloquet,[2] and quoted by Malgaigne as too exact to be improved, of this condition of the limb corresponds to nothing that has come under my observation or that is described by modern writers, and I am disposed to believe, therefore, that while the prolonged retention of fixed dressings may favor its production, yet the actual cause is to be sought elsewhere, probably in the wretched hygienic surroundings of the hospital patients of those times,

[1] Gazette Médicale de Paris, 1838, p. 36.

[2] He says: "The limb seems to lose its temperature; the skin takes on a dull white or leaden color, swells, and softens. The epidermis is raised and detached; sometimes blebs are formed with puriform or slightly viscid contents; the skin below them seems mucous and swollen; the hair falls. If the fracture is complicated by a wound the granulations swell, become flabby and livid, furnish only an ichorous pus, and bleed at the least touch. Soon ecchymoses appear, usually about the bulbs of the remaining hairs, increase in size, and spread over the entire limb. The work of repair is arrested, mobility persists at the fracture at a period when consolidation should be complete. Sometimes hemorrhages take place at different points upon the softened skin. In many cases the general condition of the patient seems entirely foreign to these local changes; the gums are firm, do not bleed, and are not swollen. The appetite, digestion, sleep, and moral are unchanged."

and in the moral and physical degradation of the class from which those patients were drawn.[1]

Mobility of the fragments, due either to the indocility of the patient, the inefficiency of the retentive apparatus, or the absence of treatment, is a common and universally admitted cause of failure or delay of union. Amesbury attributed to it an insufficient reduction of all but six of the fifty-six cases that came under his observation; Norris says that of the forty-four cases in his own table in which the probable cause of the pseudarthrosis is mentioned twenty-two may be fairly attributed to undue mobility, but he adds that the information furnished in the records of the cases cannot be entirely depended upon. Gurlt gives the details of a case in which the repair of three successive fractures, thigh, leg, and arm, was long delayed by recurring epileptic attacks, and of another in which paralysis agitans produced the same result after fracture of the humerus.

The premature use of a broken limb may not only result in secondary fracture, as has been mentioned in the preceding chapter, but may also arrest consolidation or even provoke absorption of the callus and result

[1] Of these surroundings and this degradation it cannot be easy to form an adequate conception. During one of the "glorious" periods of the history of France, say from 100 to 200 years ago, the descriptions of the conditions of the people furnished by eye-witnesses are almost incredible. The superior of a convent at Blois, in the richest part of the most fertile province, says "the poor are without bread, without clothes, without linen, without furniture, in short, deprived of everything; they are black as Moors, most of them skeletons and the children all swollen. Women and children are found dead in the roads and in the fields, their mouths filled with grass." A correspondent of Colbert writes to him "the inhabitants of this province have lived through the winter on bread made of acorns and roots, and now they eat the grass of the fields and the bark of the trees." A few years later La Bruyère writes "we see certain wild animals, male and female, scattered through the country, black, livid, burnt by the sun, attached to the soil which they cultivate with an invincible determination; they have a sort of articulate voice, and when they rise upon their feet they show a human face, and, in fact, they are men. They retire at night into dens where they live upon black bread, water, and roots." In 1698 a tax gatherer reports that in the district of Rouen which had always been one of the most industrious and well-to-do provinces "out of 700,000 inhabitants there are not 50,000 who eat their bread at their ease and sleep upon anything but straw." Similar accounts were received from all quarters, "the peasants about Moulins are black, livid, and almost hideous; they live on chestnuts and radishes like the beasts." Vauban writes "the tenth part of the people are reduced to actual beggary; of the other nine-tenths five can give no alms because they are themselves almost reduced to the same need; of the remaining four, three are very badly off." Massillon says, "our people are living in frightful misery, without beds or furniture, the only food of most of them during half the year is barley or oatmeal." These reports, and others like them, cover not a single short period, but the entire century, and the condition lasted up to the Revolution. From such people and from the corresponding class in the cities came the hospital patients.

And how were they cared for in the hospitals? The Hotel Dieu in Paris contained in 1709 more than 9000 patients, packed together four, five, nine, and even twelve in a single bed. The beds were ranged over each other like berths in a ship, and the dead, dying, and living were all mingled together. The convalescent ward could be reached only through the smallpox ward; the ward for surgical cases adjoined that occupied by the lunatics, "whose frenzied cries could be heard day and night." Not until 1790, less than one hundred years ago, were these conditions changed, and the change consisted in the removal from the hospital of a tallow chandlery and a slaughter house which with grim kinship had hitherto formed part of it, and in the reduction of the number of patients to 1800, and subsequently to 800. What value can be placed upon statistics of results obtained upon such patients and under such conditions?

in pseudarthrosis. This is most liable to occur in very oblique fractures and in those marked by much over-riding. It is not very uncommon to see a fractured limb bend under the weight of the body and present a notable deformity if the patient has been too eager to use it and prove his complete recovery. Callender[1] asserts very positively that movements communicated to a limb during the repair of fracture with a view to prevent anchylosis of neighboring joints are a frequent cause of non-union, especially movements of the elbow after fracture of the humerus, and he advises that all attempts to overcome stiffness in any joint should be postponed until the bone is firmly united.

Softening and absorption of a callus that has already formed and become firm have been observed in a number of cases, even after recovery has appeared complete and the patient has used the limb for some time, but more commonly at a period less remote from the accident. The causes usually lie in some of those diseases or complications which have been spoken of as occasionally delaying repair, such as erysipelas, phlegmonous inflammation, variola, continued fevers, scurvy, and in some few cases it has occurred without recognizable cause. Fanon[2] reports a case in which the callus softened twice after fracture of the leg. Eighty days after the injury the limb appeared solid and the patient began to use it. Two days afterwards the mobility was as great as ever. The patient was sent to the country, and in six weeks the limb was again solid. After using it for a few days again the mobility returned, and then, it having been discovered that the patient had been rachitic in youth, she was treated with the acid posphate of lime. Seven months after the accident the fracture was permanently united. I reproduce from Malgaigne and Gurlt the following cases illustrative of the other causes.

A man, forty-five years old, received a fracture of the leg which was consolidated by the fiftieth day. A month later erysipelas appeared on the leg, lasting two days; the callus disappeared and was not reproduced until two months afterwards.

In a case observed by Schelling a fracture of the femur had united so well that the patient could bear a certain weight upon the limb. He developed typhoid fever, and on the tenth day the callus had disappeared. After his death, six days later, the ends of the fragments were found bleeding as after a recent fracture and enveloped in a sort of membranous sac, which contained a small amount of black liquid blood.

A sailor broke his clavicle and was so far cured at the end of a month as to be able to use his arm as well as before the accident. Three months later, while he was hanging by the arm, the clavicle separated, and at the same time the symptoms of scurvy appeared. Consolidation did not again take place until after the cure of the scurvy at the end of six months. Under the same influence Marrigues saw the callus of a fracture that had been healed six months soften and disappear. A second consolidation followed the cure of the scurvy.

Holscher cured a pseudarthrosis of the radius by resection. A year

[1] Med. Chir. Trans., vol. 51, p. 161.
[2] L'Union Médicale, 1859, vol. ii. p. 24.

and a half afterwards the patient became greatly reduced by diarrhœa and hectic fever, and the bones, which had been soundly united, again separated.

Guersant treated a fracture of the femur in a boy ten years old; by the twentieth day firm union was obtained without shortening. The child was taken shortly afterwards with smallpox, the callus became painful, and he died on the seventh day. The autopsy showed overriding to the extent of 1½ inches; the callus was a soft ecchymotic mass, and the fragments were united by strings of a fibrous appearance. At no point in the callus was there the least sign of calcification.

Kirkbride saw a man, twenty-one years old, who, a month after he had been discharged from the hospital cured of a compound fracture of the leg, returned with an ulcer over the seat of the fracture; about three weeks later the ulcer became gangrenous, and before this was overcome the callus had been absorbed. By the application of caustic potash to the ulcer and the bare ends of the bones the former was healed, and the latter reunited in six weeks.

Finally, there is the case mentioned at the beginning of this chapter, in which a second fall caused a second fracture before the first was entirely healed, and led to the absorption, not only of the callus, but also of the entire shaft of the humerus.

Gurlt maintains, in opposition to Malgaigne and Amesbury, that there exist a few cases in which non-union has resulted without recognizable cause in strong and healthy patients, and notwithstanding favorable conditions and appropriate treatment of the fracture. He cites in support of this opinion those cases of multiple fractures in the same patient, or the same limb, of which some unite and others remain ununited, and those of fracture of the forearm, in which only one bone unites.

The *diagnosis* of non-union is made by the persistence of mobility beyond the period usually sufficient for consolidation, but the recognition of the exact condition of the parts is often difficult. This is to be obtained by palpation of the part, by recognition of the surrounding soft callus if one exists, or of the atrophied and separated ends of the bones, of the degree of mobility, by examination with acupuncture needles to determine the direction of the fracture and the relations of the fragments to each other, and by study of the subjective symptoms, the pain which accompanies even slight movements in delayed union, and the freedom from pain, even with extended movements, in true, well-established pseudarthrosis. Crepitation, which exists only in the latter case, is not common, and has the characteristics of that which is found in joints altered by disease rather than of that found after recent fracture.

The distinction between non-union and simple delay, so important in determining the method of treatment, cannot always be made by the objective symptoms; the freedom of motion, the amount of pain, and the length of time that has elapsed must be taken into account. This distinction has an important therapeutic influence, because delayed union can usually be corrected by measures that do not involve any risk to the patient's life, such as fixation of the limb, reduction of displacement, change of surroundings, better nourishment, and stimulation of the fracture; while, on the other hand, true pseudarthrosis requires

operative interference. While no definite period can be named after which pseudarthrosis alone can be said to exist, yet it may be stated, as a general rule, that the longer the time that has elapsed since the injury was received, the greater is the probability that a cure can be effected only by operation.

The following case quoted by Gurlt from Casper's *Wochenschrift*, 1846, p. 39, shows, however, that a cure is possible without operation, even after a very long period; an oblique fracture of the leg in a man more than forty years old, which had remained ununited for a year and a half, consolidated perfectly during a rest in bed for six weeks, rendered necessary by an intercurrent disease.

Many cases are recorded in which the existence of a false joint did not interfere materially with the usefulness of a limb, the patients in some cases wore braces or supports, which gave the necessary stability even when the fracture was of the leg or thigh, but in others the uselessness of the limb was so complete, and the motions communicated to it by the ordinary movements of the body so painful, that amputation has been urgently desired and occasionally performed. During the present century many operative measures have been introduced for the relief of this disability, and all have had a certain degree of success, so that amputation on account of pseudarthrosis is now rarely required. The most unfavorable cases for a cure by operation are those in which the ends of the bone are markedly atrophied.

Treatment.—Although the risks of active operative interference have been much reduced of late years, yet the rule of practice laid down many years ago in these cases still holds good; the milder measures must be first employed, and an operation should be undertaken only after these have proved unsuccessful. Simple delayed union that has existed for only a few weeks without any marked displacement of the fragments or other recognizable local cause can usually be cured by the use of the immovable dressing persevered in for three or four weeks; and in all, except perhaps the older cases, this measure should be tried and persevered in for many months, if partial gradual improvement can be recognized. With this must be combined the removal of any local or general cause, such as the overriding of the fragments, the existence of a constitutional dyscrasia, insufficient nourishment, and prolonged confinement to bed. The patient should be encouraged to get into the sunlight and the open air. Remedies taken internally have not fairly established a claim to confidence. The phosphates and magnesia have been frequently administered, and mercury, pushed to salivation, has been credited with several successes in non-syphilitic cases. Its systematic use is of course indicated in patients presenting the specific taint.

As a means of stimulating the nutrition of the limb, and thus promoting the growth and consolidation of the callus, I should try the descending constant current, the influence of which in this direction has been amply demonstrated.[1] I have met with only one instance of its use in pseudarthrosis, Broca's case referred to in Bognaud's thesis (see p. 203), and in this it seems to have been used only for the purpose of

[1] Onimus & Legros, Traité d'Electricité Médicale, 1872.

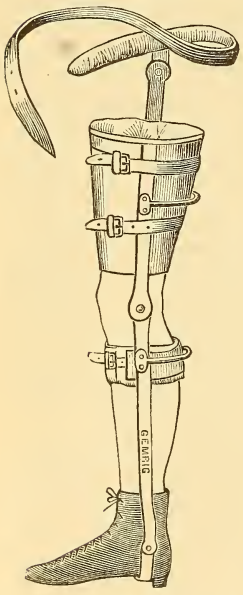
restoring their functions to the disabled nerves. Gurlt refers to three cases in which electricity was used, but does not state whether it was the interrupted or the constant current. Apparently it was used as a local irritant.

Local measures have been employed in great variety, but with only two special objects: first, that of producing a more or less severe local irritation at the fracture or in its neighborhood, with the hope of thereby stimulating the reparative process; and, second, restoring the parts by an operation to the condition of a recent but compound fracture.

The first method finds its simplest form in the application of irritants to the surface of the limb over the fracture; the tincture of iodine, blisters, and issues have been used, and successes have been claimed for each, but it seems probable that the cure was due mainly, if not entirely, to the immobility in which the limb was kept during the treatment.

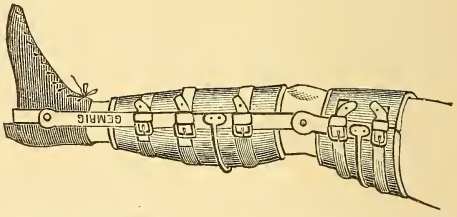
Irritation of the seat of fracture, of the callus, or of the ends of the bones is produced in a great variety of ways, some mechanical, others operative. Direct pressure with a tourniquet or graduated compresses has been used, especially in cases where the fragments have not been properly immobilized, and a large but soft callus has formed; in angular displacement it is used to restore at the same time the proper direction by pressure upon the projecting angle. Slight but frequently repeated irritation in non-union of the lower extremity is obtained by making the patient walk while the limb is protected from mobility or angular displacement by a snugly fitting apparatus. This may be one of the immovable dressings, or, better, an apparatus of leather and iron made to fit very accurately. Such a one, devised by Prof. H. H. Smith, of Philadelphia, is represented in figs. 118 and 119, and has yielded several cures. The objection to it is that the amount of the irritation, being under the control of the patient rather than of the surgeon, may be excessive, and, especially if accompanied by some mobility, may lead to more or less absorption of the callus, and thus be harmful rather than beneficial.

Fig. 118.



H. H. Smith's splint for ununited fracture of the thigh.

Fig. 119.



H. H. Smith's splint for ununited fracture of the leg.

Violent friction of the ends by seizing the fragments, one in each hand, and rubbing them against each other not only sets up a certain degree of irritation, but also ruptures fibrous bands, and may tear off similar coverings from the ends of

the bone and thus restore it partially to the condition of a recent fracture. The plan is an ancient one, and has furnished many cures. It needs to be repeated on several successive days until the seat of the fracture becomes tender and swollen, and then the limb must be carefully immobilized.

Complete rupture of the fibrous bands uniting the fragments is, according to Gurlt, one of the best and least dangerous measures that can be employed. It is most suitable in those cases in which the bone is united by dense fibrous tissue, especially if there is overriding. Anæsthesia is required. The patient is so placed that the lower fragment projects entirely beyond the edge of the bed or table, and then it is pressed forcibly downwards until the tissues are felt to crack and the lower part of the limb is brought to a right angle with the upper. It is then bent to the same distance in the opposite direction, and moved freely about until the surgeon is assured of its complete mobility, after which it is treated as a recent fracture. Such force as can be exerted by the hands of the surgeon is usually sufficient, but instruments may be required, especially to obtain the necessary extension. Gurlt says that the procedure, violent as it seems, is not followed by much reaction, and that suppuration is not to be feared. On the contrary, the reaction is sometimes insufficient to result in the formation of a callus. He prefers it to the milder method of simple permanent extension, which has been much employed in ununited fractures of the thigh with overriding.

Subcutaneous scarification of the ends with division of the fibrous bands has been used with the same object, but apparently with much less success, and has now been practically abandoned; and long fine needles have been thrust between the fragments and left in place for some time in order to provoke the desired reaction. This latter plan is sometimes very difficult of execution on account of the irregularities in the line of fracture. Malgaigne,[1] apparently, was the first to try it, in 1847, but although he made thirty-six attempts to pass the needle, all failed, and in the ten years that elapsed before the publication of his book he does not seem to have tried it again. He reports a success by Wiesel.

Irritation by galvanic currents has been used in connection with acupuncture; Agnew's tables contain five cases of fracture of the leg thus treated successfully.

The seton, passed between or beside the fragments, appears to have been employed once or twice toward the end of the last century, but its introduction as a method of treatment is undoubtedly due to Physick, of Philadelphia, who, in 1802, cured by this means an ununited fracture of the humerus. He first made extension to bring the fragments into place and then passed a silk ribbon between them and left it in place until consolidation seemed nearly complete five months after its introduction. Subsequent operators left the seton in for a much shorter period, and some, including Physick himself, found it occasionally necessary to aid its passage by a preliminary incision down to the bone. Norris's table gives 46 cases with 36 recoveries and 2 deaths thus distributed:—

[1] Loc. cit., vol. i. p. 307.

Bone.	Cases.	Cures.	Deaths.
Femur	13	9	1
Leg	10	10	
Humerus	16	10	1
Forearm	6	6	
Jaw	1	1	

Malgaigne adds to this list other cases not included in it, but mentioned in the paper, and also, apparently, the 15 instances in the table in which it is mentioned in the column of "methods which had previously failed," and constructs the following table therefrom:—

Bone.	Cases.	Cures.	Failures.	Deaths.
Humerus	30	13	16	1
Femur	18	9	8	1
Leg or tibia	14	13	1	
Either or both bones of the forearm	6	6		
Clavicle	2	2		
Jaw	1	1		
Acromion	1			
	72	44	25	3

Agnew's table contains 73 cases; 28 were cured and 8 relieved; 34 were failures, 2 died, and of 1 the result was not known. The two deaths appear to be those of Norris's table. Gurlt's analysis of his own table contains 143 instances of the use of the seton, including only the arm, forearm, thigh, and leg, with 68 cures, 10 improved, 59 failures, 3 deaths, and 3 unknown results. The 3 deaths were after operations upon the thigh (2) and arm (1), in 32 cases of the former and 68 of the latter. Agnew's table, although certainly prepared as late as 1875, contains only 10 cases reported since 1859, and only 3 of these since 1864 (1865–68), a fact which may be taken as an indication that the method is falling into disuse. I have not seen or heard of a case in the last ten years. Norris speaks of it as "one of the safest, least painful, and most effectual of the numerous operations that are performed for the cure of pseudarthrosis," but adds that the separation or direction of the fragments, or the abundant deposit of callus may prove an insurmountable obstacle to its use. In noticing this statement Gurlt points out very properly not only that these obstacles exist in a considerable proportion of cases, but also that the records of the operation do not entirely bear out Norris's estimate of its safety and efficiency, and that the largest proportion of failures is found after its use upon the humerus. An examination of the recorded cases shows that the dangers are increased, while its efficiency is not, by the prolonged retention of the seton; therefore, if used, it should be withdrawn as soon as a sufficient degree of irritation, for the recognition of which, unfortunately, no rule can be laid down, has been set up, probably, in about a week.

Perforation of the ends of the bone was first employed by Dieffenbach in 1841, but after trial in two cases, one of which was cured and the other improved, was abandoned by him for the insertion of ivory pegs. It was then suggested to Detmold[1] by a reverse process of reasoning

[1] Oral Communication.

after the publication of Dieffenbach's successes with the ivory pegs, and successfully used by him September 4th, 1850,[1] and again, he tells me, shortly afterwards in the presence of a committee of the New York Academy of Medicine. The method, however, is commonly associated with the name of the late Prof. Brainard, of Chicago, who forced it upon the attention of the profession in various articles.[2] The theory of the method is that the perforation of each fragment at one or more points near the line of fracture is sufficient to excite the desired productive osteitis without danger of suppuration. Brainard used a triangular pointed drill made of very hard steel, and placed the limb during the operation in a short metal splint perforated at various points. The drill was passed through one of these perforations and prevented from penetrating too deeply by a sliding clamp which could be fixed by a thumb-screw at any desired point on its shaft. He recommended that after the drill had been forced well into or through the bone it should be partly withdrawn and made to penetrate again at another point or in a different direction.

Agnew's table contains 51 cases thus treated: 32 were cured, 2 improved, and in 17 the operation failed.

Bone.	Cases.	Cures.	Improved.	Failures.
Humerus	14	6	1	7
Radius and ulna	7	4		3
Femur	8	5		3
Tibia and fibula	19	14	1	4
Patella	1	1		
Inferior maxilla	2	2		

So far as I am able to judge, the operation is regarded favorably by American surgeons, and is among the first of the operative methods employed in any given case. It is unsuited to cases in which there is much irreducible longitudinal displacement. In the cases in which I have seen it used but little force has been required to perforate the bone. In a case reported by Dr. Weir,[3] in which a drill with a flattened point was used, the point of the instrument broke and remained in the bone; the patient died of erysipelas, apparently originating in an abrasion of the skin.

In 1846 Dieffenbach treated successfully an ununited fracture of the humerus by inserting an ivory peg into each fragment half an inch from its end, and leaving them in place for two weeks. The plan was based upon the knowledge obtained by experiments upon animals that the presence of a foreign body in bone provokes an abundant formation in its neighborhood. The operation is done by passing a narrow-bladed knife directly down to the bone and following it with a gimlet or drill, which is then made to perforate the bone completely. A cylindrical peg of

[1] This case is reported in the New York Med. Gazette, 1850, p. 232. The fracture was of the tibia, and two holes were bored transversely, and one obliquely upwards, the latter beginning 1½ inches below the fracture and penetrating the upper fragment for an inch or more. Sandford is also referred to by Brainard as having perforated the bone before 1850, but his operation (Trans. Am. Med. Association, 1850, p. 355) was simply division of the fibrous bone with a tenotome.

[2] The principal one is in the Transactions of the Am. Med. Association, 1854, p. 557. Thirteen cases were reported by him in the Chicago Med. Journal, Sept. 1858.

[3] New York Med. Record, March 8, 1879, p. 235.

ivory, slightly smaller than the gimlet, is oiled and driven into the opening until it projects about half an inch on the opposite side. The other fragment is treated in the same manner, a dressing of oakum or lint placed over the incisions, and the pegs, the ends of which are left projecting above the surface, withdrawn after deep pain begins to be felt in the bone. If the tissue between the fragments is lax it must be lacerated by incision, or by free movements.

The operation exposes to the chance of excessive suppuration and other accidents of compound fracture. Gurlt's 21 cases of the operation and its modifications show no deaths and 14 cures; Agnew's 58 similar cases give 1 death and 36 cures.

The modifications consist mainly in the substitution of metal for the ivory pegs, and in sometimes using the peg to fasten the fragments together by driving it through both. Occasionally the pegs have been cut off level with the bone and the wound left to close over them. Under these circumstances the ivory pegs become eroded, and may disappear entirely by absorption or become encysted.

Trendelenburg exhibited at the Tenth Congress of the German Gesellschaft für Chirurgie[1] a specimen of pseudarthrosis of the lower end of the femur which had been cured by the introduction of an ivory peg through the knee-joint. At the death of the patient, two and a half years afterwards, the peg was found unchanged, except by the separation of the end which had been left projecting into the joint, and which was found imbedded in the capsule. At the same meeting Riedinger exhibited preparations to show the superiority of bone pegs to those made of ivory. The bone pegs apparently became structurally united with the bone into which they were introduced.

Caustic potash has been applied with success to the ends of the bones after division or removal of the intermediate fibrous tissue; the application is continued until a black slough forms, and is repeated if necessary. The actual cautery has been used in the same manner.

Resection of the end of one or both fragments was first performed for the relief of pseudarthrosis in 1760 at the suggestion of White of Manchester, and is said by Gurlt to have been, with the exception of the seton, the method most frequently resorted to. It owed this favor doubtless to its radical character, to the promise it held out of speedy union by restoration of the parts to the condition of a recent fracture and their accurate coaptation; but its dangers, which were those of compound fracture, proved so great that many surgeons hesitated to employ it, and Sir Benjamin Brodie condemned it entirely. The great reduction of these dangers by the use of antiseptic dressings has again brought it into favor, and the journals now contain comparatively frequent reports of its use. The operation consists in the division or excision of the intermediate fibrous band, and the freshening of one or both fragments by the saw or chisel, and sometimes in the fastening of them together by a wire suture or ligature, or by transfixion with pins of ivory or metal.

A longitudinal incision is made over the fracture on the side that per-

[1] Supplement to Centralblatt für Chirurgie, 1881, No. 20, p. 21.

mits the easiest access to the bone with avoidance of the main vessels and nerves, and is carried down to the bone by drawing the muscles aside, or by cutting through them if necessary. The uniting band is divided or stripped off, each end turned out, and its surface freshened with the saw or bone-pliers, the fresh surfaces being so shaped as to favor their subsequent coaptation to the greatest possible extent. If the bone is covered by thick masses of muscle, or if the fracture is near a joint it is not always easy or even possible to turn out the ends, and then the freshening must be done with a chain-saw, metacarpal saw, or chisel. The periosteum should be preserved to favor the formation of an external callus, but it does not seem desirable to carry this to the extent practised in one or two cases of stripping up a sleeve of periosteum from each end and sawing off the corresponding parts of the bone, so that one sleeve can be engaged within the other.

Only as much bone should be taken away as is necessary to thoroughly freshen the ends and make the desired coaptation possible; but the loss of substance involved in this removal is less important in the upper than in the lower extremity.

If the surgeon desires to fasten the bones together he may surround them with a loop of wire, if the line of contact is sufficiently oblique, or perforate them with a drill and pass a wire through the holes thus made. The fragments are brought close together and fixed by twisting the wire, or by passing a canula down over its ends to the bone and fixing them by twisting on the outside. Or the ends of the wire may be cut short, if antiseptic dressings are used, and left to become encysted. If the line of fracture is oblique, a metal peg or screw may be driven through one fragment into the other. The wire or pin should be left in place for a length of time that varies with the size of the bone and the consequent rapidity of repair, but, as a general rule, it may be removed in the course of two or three weeks. The wire is removed by untwisting it and drawing it out, a procedure which is sometimes difficult. MacCormac has sought to obviate this difficulty by passing a stout pin through the bones and placing the wire in the form of a figure-of-eight over its two ends; by the withdrawal of the pin the wire is freed.

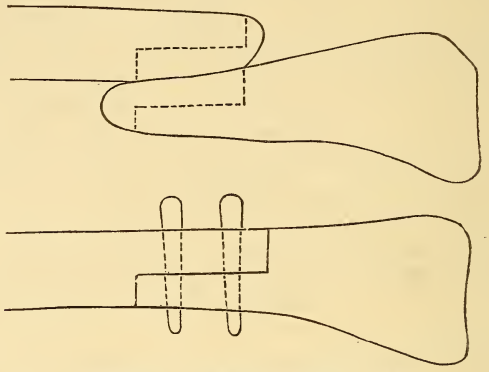
Volkmann[1] treated a pseudarthrosis of the tibia with much overriding by notching each end for two inches and fastening them together by means of two ivory pegs, as shown in fig. 120. A gypsum splint was applied and the wound treated antiseptically; it healed promptly down to a small fistula, and the pegs which had then become loose and eroded were withdrawn in the seventh week. No mobility could be detected at that time, and the patient was dismissed cured four weeks afterwards.

In one case Roux sought to immobilize the fragments by sharpening one and forcing it into the medullary canal of the other, and apparently with success; but unfortunately the patient had a fall two months afterwards and broke the arm again, after which amputation became necessary. Hamilton says he has done the same, but does not state the result Holthouse[2] tried it unsuccessfully.

[1] Berlin. Klinischer Wochenschrift, 1875, p. 221.
[2] Lancet, 1864, i. p. 326.

The indications which determine the choice of a method of treatment have been pointed out in connection with the different methods, and they vary so greatly with the pathological conditions of the fracture that it is hardly possible to summarize them profitably except in the most general

Fig. 120.



Volkmann's operation for pseudarthrosis.

terms. As a rule, the milder methods are to be preferred in all cases in which there is reason to consider the case as simply one of delayed union, and these measures must of course be directed to removing the cause of the delay, whether it be a general or constitutional vice or a local obstacle, such as mobility or displacement. In addition, local irritation by friction or by perforation with a drill may properly be used. Resection, I believe, may be stripped of most of its danger by strict antiseptic precautions, and in cases of real pseudarthrosis and disease of the fragments it is the only method that holds out much prospect of success.

Palliative measures consist in the application to the limb of an apparatus that will supply the necessary solidity. Such an apparatus must ordinarily consist of a snugly fitting leather case, possibly strengthened by longitudinal strips of metal.

Amputation may be required to save the patient's life after the failure of an operation to cure the pseudarthrosis and the occurrence of profuse suppuration or gangrene; or it may be demanded by the patient as a relief from a painful and burdensome limb, especially if the non-union is associated with necrosis or caries and interminable suppuration.

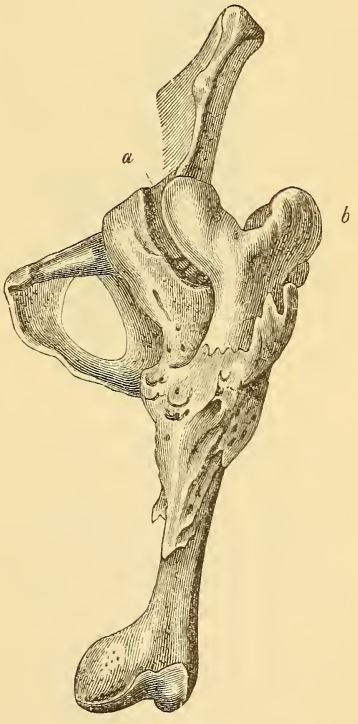
CHAPTER X.

DEFORMED, FAULTY, OR VICIOUS UNION.

Besides the temporary and permanent causes already mentioned which may interfere with the functions of a limb that has been broken, there are others yet to be considered which depend upon the irregular union and position of non-articular portions of the bone, upon the excessive size of the callus, or upon the inclusion in the latter of muscles or tendons.

The inclusion of a muscle or tendon in a callus is not a common complication, and most of the recorded instances have been in the forearm or leg. The following case is a noteworthy example: Chassaignac[1] presented a specimen of fracture of the radius and ulna with complete fusion of the bones. The pronator quadratus was atrophied, and pronation and supination abolished. The extensors of the index finger were transformed into a fibrous band attached to the callus. One of the extensors and one of the flexors of the little finger were fixed in like manner and interrupted at the callus.

Fig. 121.



Vicious union after fracture of the femur. (Gurlt.)

It is possible that in the earlier stages of the less severe cases of this character the muscles or tendons might be successfully and safely freed by an operation under the antiseptic method, but if the tissue has itself become ossified nothing can be hoped for from any treatment.

Mention has been made in Chapter VII. of the inclusion of a nerve within a callus, and of the possible pressure of an exuberant callus upon the nerves that pass over it. It seems probable that the latter is not a sufficient cause of the pain that is experienced in such cases, but must be aided by previous injury to the nerve resulting in a neu-

[1] Bull. de la Soc. Anatomique, 1842–43, p. 339.

ritis which is kept up perhaps by the pressure. Usually when an overgrown callus produces disability, it does so by establishing firm union with an adjacent bone, or by opposing a fixed mechanical obstacle to the motions of a joint. Common examples of the former are furnished by fractures of the forearm, and an extreme one of the latter is represented in figure 121. It is taken from a specimen of fracture of the shaft of the femur united with much shortening. Movements at the hip-joint were entirely prevented by a bridge of bone uniting the pelvis with the seat of fracture.

The most frequent kind of vicious union, and the one commonly referred to when this term is used, is that in which the fragments are united with a degree of displacement that interferes seriously with the form and functions of the limb. It is convenient for the present purpose to divide this pathological group into two principal varieties, differing in their anatomical characteristics and in the nature of the resulting disability, according as the fracture involves the shaft or the articular end of a bone. Of these, only the former will be here considered; its examples present a certain degree of uniformity in their elements and treatment, while the latter can be better considered in detail and in connection with the different fractures.

Vicious union of the shaft of a long bone is union with angular, longitudinal, lateral, or rotatory displacement to an extent which causes a notable deformity or diminution of function. It is most important, most likely to require surgical treatment, after fracture of the leg or thigh, because changes in the length or shape of the lower extremity are more commonly productive of functional disabilities than similar changes in the arm, and more amenable to treatment than those of the forearm.

This disability may be due not only to shortening or rotation of the limb, but also to change in the direction of the long axis of the lower segment which makes it necessary to evert the foot in order to bring the sole flat upon the ground, and thus the internal lateral ligament of the ankle is exposed to an excessive and constant strain. Or the weight of the body may cause pain at the seat of fracture by increasing the abnormal angle existing there, or the point of a fragment may irritate the soft parts and cause persistent ulceration.

The causes are the same as those which produce displacements, for the condition is simply the persistence of a displacement produced at the time of the accident, and left unreduced, or occurring in the course of the treatment as the result of defective contention, of too early use of the limb, or of insubordination on the part of the patient.

Of 149 cases collected by Gurlt of vicious union requiring an operation for its correction 71 were of the thigh, 59 of the leg, 12 of the arm, and 7 of the forearm. Of the fractures of the thigh which resulted in it the position was indicated in 56; in 20 of these it was in the upper third, in 10 above the middle, and in 21 at the middle. The character of the displacement was indicated in 55; in 38 of these it was angular with the convexity directed outwards or outwards and backwards, and in 9 outwards and forwards. Of 37 fractures of the leg in which the location of the fracture is mentioned, 18 were in the lower third and 8 below the middle; of 33 in which the direction of the apex of the angle formed

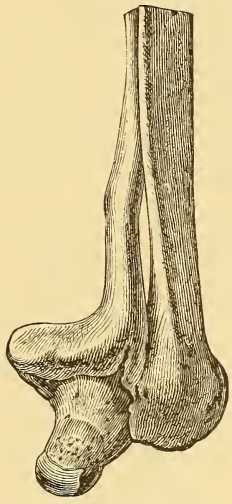
by the displacement is given, it was forwards in 18, outwards in 8, and inwards in 7.

In 3 cases in which badly united fracture of the fibula led to operative interference, the symptoms were: a depression above the external malleolus, marked prominence of the internal malleolus, increase of the distance between the two, and extreme eversion of the sole of the foot; and in one case the astragalus had slipped up between the bones of the leg. When this displacement is associated with bony ankylosis of the ankle-joint (figures 122 and 123) it cannot be corrected, and the only treatment is resection or amputation.

Fig. 122.

Vicious union after fracture of the fibula.

Fig. 123.



Vicious union after fracture of the fibula 2½ inches above the tip of the malleolus.

The methods of treatment present four varieties: 1st, the straightening of the limb by immediate infraction or bending of the callus, or gradually by a moderate force constantly applied; 2d, forcible rupture of the callus; 3d, division of the callus; 4th, resection of projecting portions of the bone.

1. *Infraction or Bending of the Callus.*—Bending of the callus at a single sitting is possible only before complete ossification has taken place, but gradual bending and straightening by a moderate force acting constantly can be accomplished even after three or four months. This method is only the later application of that inspection and correction which was recommended by the older surgeons to be made when neces-

sary in the course of any case, and has been practised from the earliest days. The operative procedure in the rapid form consists of extension, counter-extension, and coaptation, the latter being made by pressure upon the prominent angle by the hands alone, or with the aid of the knee. If the angular displacement is associated with overriding extension is necessary both to reduce the displacement and to maintain the reduction when obtained. The operation is simply the reduction of a displacement while the callus is still incomplete, and after this is done the usual precautions are still to be taken to secure immobility in a good position.

Gradual bending is accomplished either by extension and counter-extension in the usual manner, or by constant lateral pressure upon the projecting angle. Two principal methods of exerting the latter are in use: a splint is applied on the open side of the angle and the limb is bound to it by a circular roller or bands tightened several times each day, or by elastic bands; or the splint is applied upon the convex side and the distal segment of the limb drawn towards it by the same means. Careful padding is needed at all points of pressure. This method is apt to be painful, and is inferior in most cases to the rapid method done, if necessary, with the aid of anæsthesia.

The change in the direction of the bone is accompanied by the breaking of some portions of the callus, and the difference, therefore, between this and the second method, in which the callus is completely broken, is one of degree rather than of kind, and the surgeon in attempting either may find his object accomplished by the other.

2. *Rupture of the Callus.*—This method, which appears to have been used in very early times, is mentioned, according to Malgaigne, by the earlier writers only to be condemned because it was feared the bones would break at other than the points desired. Toward the end of the 17th century, Purman[1] used a machine for the purpose, but his example seems to have had no followers until in 1782 or 1783 Bosch found an old iron apparatus which appeared to have been made for this purpose. He had another constructed in a modified form and used it successfully upon two cases in 1783, one of them being a fracture of the femur in the twenty-eighth week, the other a fracture of the leg. He repeated the operation a number of times, and once, in 1811, in the presence of Oesterlen, who repeated it in 1817 and published the case together with several of Bosch's.

Bosch's original instrument was like a book-binder's press; he modified it a number of times and many instruments have since been devised by different surgeons. They are known as osteoclasts, and the force is usually exerted by means of a screw. One of the simplest, Rizzoli's, consists of a stout steel bar supporting a pad in the centre and a ring at each end, all movable upon it. The limb is passed through the rings which are then fixed at the selected points, and the intermediate pad is screwed down upon the bone at the point where the fracture is to be made. A very powerful instrument capable of accurate adjustment has

[1] Grosser und ganz neu gewundener Lorbeer-Krantz, oder Wund-Artzney, 1692. Quoted by Gurlt.

been made by Collin & Co., of Paris, for the purpose of making supracondyloid fracture of the femur for the relief of genu valgum, and could probably be used with advantage also in cases of vicious union.[1] Prof. Sands[2] speaks highly of the accuracy and certainty with which it produces its results.

The injuries inflicted in the rupture of a callus are less than those accompanying an ordinary fracture, because the force required to effect it is less and is applied in such a manner that it does not cause displacement and laceration of the soft parts. It has already been shown that when fragments are united with much displacement, which is the condition in vicious union, the callus is usually comparatively scanty and remains friable for a considerable time, and experience has shown that secondary fractures produced intentionally or by accident heal, as a rule, more promptly and with less reaction than primary fractures. Of the numerous cases collected by Gurlt there was but one in which suppuration occurred, and in that the ultimate result was good, and only one in which subsequent union failed. Malgaigne, on the other hand, refers to three cases in which death followed the operation. In the first, performed by Ali Rodoham, the patient, a man 70 years old, appears to have died upon the table; in the second, reported by Morgagni, the patient died of the remoter complications of the fracture; and in the third, reported by Laugier, death took place an hour and a half after the operation.

Gurlt gives a table, made up of cases collected by him, in which the callus was ruptured, with or without the aid of instruments, after the lapse of the period of time which is usually sufficient for complete consolidation, that is, ten weeks for fractures of the thigh and eight weeks for those of the leg. It is arranged in two groups according to the age of the patients, those under fifteen years composing one, all older ones the other. The cases show, as he points out, that forcible rupture is a successful and safe method of treatment, even after the lapse of a period of time that has often been considered an absolute contraindication. In 10 of the adult cases more than six months had elapsed, the longest period being twenty-one months, and the same length of time in 8 of the younger cases, in 3 of them two years, and in 2 one year. The average age of the adult cases was thirty-three years, that of the young cases about seven years, the oldest being sixty-four, the youngest one and a half; 27 cases were of the thigh, 22 of the leg, and 6 of the humerus.

The various kinds of medical treatment which have been suggested or employed, with a view to softening the callus and making its rupture easier, have no effect beyond causing the loss of valuable time, and the perforation of the callus at several points with a drill for the same purpose seems not to be of sufficient value to compensate for the additional risk. Gurlt's table contains 4 cases in which this latter was done; two were successful, in one the fracture could not be produced, and in the remaining one suppuration ensued and caused death. If the drill is used the wounds should be allowed to heal before the callus is broken.

[1] For an instance of its successful use to relieve faulty union at the ankle, see Bull. de la Société de Chirurgie, 1880, p. 419, or chapter xxvii. of this book.

[2] Proceedings of N. Y. Surgical Soc., May 10, 1881, in the Medical Record, 1881.

The operation consists either in extension and counter-extension by the hands of the operator and his assistants, or by specially contrived instruments, or in lateral pressure with the hands and knee, or with the limb resting on a table so that the weight of the surgeon's body can be used as the rupturing force, or in the use of the osteoclast. Usually lateral force is exerted upon or near the apex of the angle, that is, in the direction in which it tends to diminish the displacement, but Dieffenbach has recommended that it should be exerted at first in the opposite direction, increasing the angle, as is often done in cases of ankylosis. As soon as the surgeon is made aware by the sound or the mobility that the callus has been broken he reduces the displacement as gently as possible by traction or lateral pressure, and when this reduction is complete, or has been carried as far as is considered prudent, he applies the dressings.

I find no mention made by the authors of rupture of the main arteries or nerves during this operation, and yet it seems a not impossible accident when the deformity has lasted a long time and these organs lie on the side of the concavity.

In this connection may be mentioned also an operation proposed and performed by Rizzoli in 1847, that of fracturing the corresponding bone of the other limb and seeking its union with a shortening equal to that of the first. The idea appears to have been suggested to Rizzoli, two or three years before, by a case of fracture of the right femur of a man whose left femur had been broken twenty years before and had united with two inches of shortening. The new fracture was left without support until its shortening equalled that of the other, and then it was placed in a fixed apparatus and allowed to unite in that position. The patient was afterwards able to walk without limping.

A similar case had been treated in the same manner at Brussels in 1840, and a shortening of three inches thus compensated for.

I am not aware that Rizzoli's operation has ever been repeated, and it does not seem probable that many surgeons would be willing to recommend this means of correcting an inequality in length which could be sufficiently well met by a cork sole.[1]

3. *Division of the Callus.*—This method differs from the preceding one, in that it substitutes a compound fracture for a simple one. It consists essentially in an incision through the soft parts down to the bone and the division of the latter by a saw, chisel, or bone-pliers. According to Malgaigne it was first performed by Paulus Ægineta, and is referred to by Hildanus as having been performed by a surgeon of his time. Malgaigne mentions nine additional cases, two of simple division, and seven of resection, and Gurlt gives in his table thirty-eight cases, about half of which antedate the publication of Malgaigne's book.

So far as the essence of the operation is concerned, it is immaterial whether the bone is simply divided or a wedge-shaped piece removed; the additional danger in the latter case is due to the greater laceration

[1] A well-known New York surgeon, however, about fifteen years ago excised four inches of the shaft of a sound femur in order to make the length of the limb the same as that of the opposite one, which had been shortened by excision of the hip-joint. This case also remains unique.

of the soft parts. This is a detail which depends upon the character of the displacement and the form of the callus. Langenbeck modified the procedure by using a very narrow saw for the division of the bone. He first made an incision about half an inch long, through which he introduced a drill and perforated the bone; he then passed the saw into the hole, and cutting first in one direction and then in the other, divided the bone almost entirely. After the wound thus made had filled with granulations, he fractured the bone at the weakened point and reduced the displacement.

Within the last four or five years many osteotomies have been performed upon the curved bones of rachitic children, and upon the femur in cases of genu valgum under antiseptic precautions with an almost entire absence of dangerous accidents or complications. The method of procedure is to make a short longitudinal incision down to the bone, insert a chisel, turn it transversely, and divide the bone by repeated blows with a heavy mallet, the limb resting meanwhile upon a sand-bag. The wound is then syringed out with a $2\frac{1}{2}$ per cent. solution of carbolic acid, dressed with carbolized gauze, and the limb placed in a splint. Usually the dressing does not need to be changed, and the wound heals by primary union. If the cellular tissue projects through the incision in the skin it should be cut away below the level of the latter so as not to interfere with its union. It is recommended also, that the sides of the wound should be kept in apposition by a narrow strip of adhesive plaster crossing its centre. The uncovered portion of the wound provides for the escape of any discharge.

I have not met with any case in which this method has been applied to a badly united fracture, although Malgaigne[1] proposed it as less dangerous than division with a saw, but I feel sure it would be equally serviceable in cases of angular or rotatory displacement without such overriding as would greatly increase the thickness of the bone at the point where the fracture would have to be made.

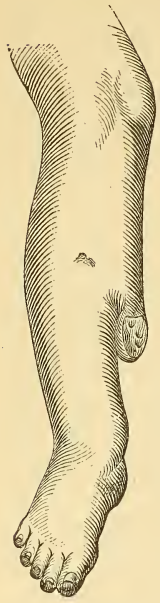
In long-standing cases in which the disability is due more to the deflected position of the foot than to the shortening, as in some badly united fractures of the leg, and when the principal indication, therefore, is merely to correct the faulty direction of the lower segment, and in similar cases of extreme angular displacement of the thigh in which there is reason to suppose that the tissues on the concave side have become permanently shortened, it is better to resect a V-shaped piece, or even a piece of considerable length, than simply to divide the bone, so that the limb may be made straight without undue or dangerous tension of the soft parts.

In view of the great diminution of dangers by the use of the antiseptic methods, the tabulation of the results obtained under the other methods of treatment does not seem necessary, or even useful. It is sufficient to say that the 38 cases collected by Gurlt give 25 cures, 1 improvement, 1 failure, 2 amputations, and 7 deaths, and in 2 the result is unknown.

4. *Resection of a Projecting Fragment.*—In some cases the defect of the union is found not in shortening or change of the direction of the

[1] Loc. cit., vol. i. p. 339.

Fig. 124.



Vicious union after fracture of the tibia.

limb, but simply in the projection of the end of one of the fragments which by its pressure may irritate and cause ulceration of the skin, and be the source of much discomfort, or even disability. The same condition may, but much more rarely, be the consequence of an overgrowth of the callus. It occurs most frequently after oblique fracture of the humerus or tibia (fig. 124).

The indication is plain, and the treatment simple and free from danger. A longitudinal incision is made over the projecting bone, and the latter freely exposed and then removed with the saw, bone-pliers, or chisel. The sides of the incision are then brought together and primary union sought except at the point where the drainage tube is left.

In making a choice among these means of correcting vicious union the surgeon must be guided by two facts: 1st, that a simple fracture is a lesion which does not practically involve any danger to the patient's life, while a compound fracture, notwithstanding the vastly improved results obtained under antiseptic treatment, must be considered as a much graver injury; and 2d, that the less the length of the time that has elapsed since the receipt of the original injury the greater is the probability of success by the milder methods. The first will lead him to employ the milder methods whenever there is any hope of succeeding by their aid; the second will guide him in the choice between immediate or gradual straightening and forcible rupture, or, when taken in connection with the extent and character of the displacement, may force him to resort to the more dangerous division of the callus.

In all cases in which not more than two months have elapsed, the first method holds out a good prospect of success, and it should be resorted to at once without losing any time in vain measures intended to soften the callus. In fractures with much displacement this period may be considerably lengthened, for these are the fractures in which repair takes place most slowly, and the callus remains soft or friable longest.

When a choice can be made forcible rupture is to be preferred to division by the saw. One objection which has been urged against it, that of an alleged difficulty of producing the fracture at the desired point, has been shown to be unfounded. The instruments at our disposal enable the fracture to be made with great precision. Another objection, that of subsequent failure of the bones to unite, has been urged against refracture. There is, so far as I know, but one recorded instance of such failure, and the objection, if it be a valid one, is equally good against division.

If division is chosen it must be performed with the strictest attention to the details of the antiseptic method; and resection of a portion of the callus or of the bone must be made whenever there is reason to suppose that the tissues in the concavity of the limb are permanently shortened.

Subcutaneous division of the tendo Achillis may take the place of this resection in some faulty unions of the leg with an anterior angle.

I have no means of determining the extent to which surgical interference is justifiable in cases in which a callus has united the bones of the forearm and destroyed the function of rotation of the wrist.

The resection of a projecting fragment or portion of callus is an easy and safe means of removing what may be the cause of serious discomfort or disability, and the surgeon should not hesitate to do it when a plain indication arises.

CHAPTER XI.

GENERAL PROGNOSIS.

The prognosis after fracture involves consideration of the effects of the injury with respect to the prolongation of life, the preservation of the limb, its usefulness if preserved, and the period of time required for convalescence. The different factors in this prognosis have been considered, many of them in detail, in the preceding chapters, and I shall therefore only group them here for a more convenient general view. It has been said recently by a prominent German surgeon that a fracture is now to be considered rather as an inconvenience than as a misfortune, but while the remark may contain an element of truth, it is far too sweeping. We have seen that the life of the patient may be endangered not only by a compound fracture of a limb but also by a simple one, and that in almost any case the functions of the part are liable to be crippled for a considerable period of time, and perhaps permanently.

The prognosis varies with the age and condition of the patient, the character, position, and origin of the fracture, and the complications to which it may give rise.

1*st*. *The Patient*.—*Sex* does not affect the prognosis. *Age* has a great influence upon it; the younger the patient the better the prognosis. In children the bones unite more promptly, and usually with less permanent deformity, and compound fractures are less serious. But in fractures involving or in close proximity to joints the prognosis, *quâ* function, is affected unfavorably by the strong tendency that exists during youth and childhood to excessive formation of callus when the displacement is not entirely corrected. On the other hand, if the injury is such as to call for excision of the joint the probability of a reproduction of bone sufficient to create a new and serviceable joint is good. In old people the prognosis is worse because in the more severe cases they are less able to recover from the injury, escape the complications, and bear the necessary confinement to the bed. The latter is an especially grave element in the prognosis which is further aggravated by the pain. Furthermore, their joints are more likely to become stiffened, and their tissues to remain engorged and rigid. They are also especially liable to certain fractures, such as those of the wrist and neck of the femur, which entail necessarily a greater or less degree of deformity or disability.

The *general condition* of the patient seems to be without any very serious importance so far as the repair of the fracture is concerned; even in those rare cases in which there is a congenital or acquired predisposition to fracture, the bones, as we have seen, unite within the usual period. On the other hand, the existence of a special dyscrasia such as syphilis or scurvy, or an acute intercurrent disease may delay

or entirely prevent repair. Paralysis of the affected limb may or may not affect the process, according to conditions which have been elsewhere detailed.

2*d*. *The Fracture.*—Fractures by direct violence are, as a rule, more severe than those by indirect violence, because in addition to those lesions which are common to both forms there is also in the former the bruising of the soft parts produced by the external force, and the consequent increased probability of suppuration. And when the violence is great, as in the passage of a car-wheel across a limb, the bone is usually comminuted, the muscles torn, and the vessels and nerves bruised and lacerated. In gunshot fractures the prognosis is especially bad as regards the preservation of life or limb, the duration of the treatment, and the functional consequences. They are frequently associated with injury to important vessels or nerves, the tissues traversed by the ball are so bruised that suppuration is practically inevitable, and as bones deeply placed are as liable to be thus broken as the superficial ones the chances of efficient drainage are less. In addition, the injury to the bone itself is more severe, for it is shattered, splintered, and usually fissured.

Although improved methods of treatment have reduced the mortality after compound fracture the prognosis still remains much more serious than after simple fracture. Repair takes place more slowly, the patient is exposed to more numerous and more serious complications during its progress, and the functional disability is usually greater and more prolonged. When such a fracture involved a large joint, as the knee, amputation was formerly considered almost inevitable; we have now learned that the limb can often be preserved, sometimes even with a useful joint, sometimes only after excision, but the risk is always a great one and secondary amputation may be required.

Fractures of some bones carry with them special risks because of their relations to important viscera, as fractures of the skull, the spinal column, the hyoid bone or larynx, the ribs, and the pelvis.

Fractures of the short or spongy bones unite more promptly and usually with less deformity than those of the shafts of the long bones, and the same is true of the spongy ends of the latter except when the fracture enters the joint. Small bones heal more quickly than large ones, and the bones of the face more quickly perhaps than any others. The shafts of the long bones are attached to so many muscles, the tendency to contraction of the latter is so constant, and the counteracting effect of the different groups upon each other is so completely annulled by the fracture of the lever that the probability of union with more or less displacement and shortening is very great. This result may give occasion to so much dissatisfaction on the part of the patient that it is important it should be known to be unavoidable under many circumstances. Its cause, as we have seen, may lie in conditions that are entirely beyond the control of the surgeon, and he must not be held responsible for the limitations of our art. The surgical section of the American Medical Association[1] meeting at Chicago in 1877 gave expression to this fact in formal resolutions adopted after discussion of the subject. They said:

[1] Transactions, vol. xxviii. p. 507.

"It is the opinion of this Section that shortening in cases of fracture of long bones is the rule in practice, regardless of any of the plans of treatment now in use."

A controversy, regrettable on account of the personal issues which it has raised, has been since carried on between two of our prominent surgeons upon this point, and has brought out very plainly the fact that even if the resolutions may be considered too sweeping by some they express what is undeniably true in many cases, the impossibility of insuring union without shortening. The assertion that a good, even perfect, result after fracture of the femur can be insured by making complete reduction under ether, and then so fixing the limb in an immovable plaster apparatus as to maintain the reduction until union has taken place will be accepted by all as the correct statement of a principle, but of one which unfortunately cannot always be embodied in practice. The action of the muscles is not the only cause of displacement, and even when it is the cause permanent extension will not always overcome it; and, secondly, the plaster dressing does not furnish complete permanent extension, because of the absence of an upper fixed point of support.

In superficial bones the displacement is more easily recognized, and for this as well as for other reasons the prognosis is somewhat better than after fracture of bones that are covered by thick layers of muscles. When the corresponding bones of both limbs are broken the surgeon loses the standard of length and form furnished in other cases by the uninjured limb; but, except perhaps in the case of the femur, this loss is not serious. The fracture of one of two parallel bones has a better prognosis than that of both, because the remaining bone acts as a splint and subsequent union of the two bones by the callus is less probable, a union which entails great functional disability in the case of the forearm, but is without serious consequences in the leg or ribs. Fracture of a bone at two or more points is very likely to be followed by permanent shortening, because of the difficulty of restoring the intermediate fragment to its proper position.

In articular fractures the prognosis must be guarded, for in addition to the functional losses that may be caused, there is also danger of suppuration of the joint, of caries or necrosis, or of the production of a chronic synovitis, especially in the young and strumous. If the fracture is not comminuted and if the displacements can be reduced, recovery with almost complete preservation of function may be obtained, but such a result is rare. In many cases, as in fracture of the neck of the femur or of the humerus, the displacement can be neither recognized nor corrected, and in others, at the same points, bony union is practically impossible, and although such patients may be able to use the limb with some comfort and freedom, the great majority are permanently and seriously crippled. Fractures of the patella and coronoid process of the ulna may be expected to heal by fibrous union, and the degree of disability depends partly upon the length of the fibrous band.

In fractures combined with dislocation of the same bone, the prognosis, with reference to function, depends largely upon the possibility of reducing the dislocation. When the fracture is situated upon the shaft at some distance from the joint the reduction of the dislocation under ether

will usually present much more than the usual difficulty, and when the fracture is near the joint and the dislocated fragment is a small one it may be impossible to act upon it at the time, and the reduction must be made, if at all, after the fracture has united.

The less extensive the fracture, the better the prognosis. Infractions heal most quickly and with least tendency to displacement; transverse fractures more quickly than oblique ones, because of the greater tendency of the latter to shortening and transverse displacement, Splintered fractures and fractures with long fissures involving the medullary canal are especially liable, if compound, to suppuration and to dangerous osteo-myelitis, and the former are exposed, as has been shown in Chapter VII., to the late formation of an abscess after apparent recovery.

For the prognosis in the different complications which may arise in the course of the treatment the reader is referred to the sections specially devoted to them.

CHAPTER XII.

FRACTURES OF THE SKULL.

This class of injuries, one of the most obscure and important in surgery, owes its special interest not to the lesion of the bone, but to those of the brain or its coverings which are so frequently associated with it and lead so often to a fatal result. From the earliest times injuries of the head have been attentively studied with regard both to the mechanical questions involved in the production of fractures and to the treatment to be pursued. The coexistence of a wound of the soft parts has always been looked upon as a formidable complication, one which added to the dangers arising from pressure upon the brain those due to the contact of the air with the exposed parts, and therefore, as active interference could not be made in any case of simple fracture without creating this communication, the strong tendency of all surgeons in the last half century, I may say the positive teaching of all, was to temporize until the appearance of symptoms of intra-cranial inflammation should force the surgeon to attempt the removal of the actual or supposed cause.[1] In some cases the reaction was slight or entirely absent and the patients got well under this expectant plan; in others the tardily undertaken operation failed to arrest the progress of the dangerous symptoms or seemed even to make it more rapid, and thus surgeons were confirmed in the policy of non-interference, not only in cases where there was no proof of fracture but also in others with both fracture and depression of the bone but without external wound.

While such views were held concerning treatment, fractures of the skull were not to be separated practically from the larger class of injuries of the head, and had but little in common with fractures of the limbs. But now the practice is changing under the influence of the improved methods of treating wounds, and even when a fracture is not compound many surgeons do not now hesitate to cut down upon the bone and apply the trephine if depression or even a fissure is found, so that it seems desirable to depart from the practice of former writers and include this class of injuries also among fractures.

Fractures of the skull are by no means rare; in the table of statistics given in Chapter I., there are 757 cases of this kind in a total of 51,398 fractures. They occur in patients of all ages and both sexes, but are most frequent in adult males for reasons depending upon the greater exposure of that class of the community to the accidents and violences which are the most common causes of the lesion. These causes are

[1] Views radically opposed to this were held by some of the earlier surgeons, notably Percy and Boyer, who advised the application of the trephine even in cases of simple contusion without fracture, as a means of preventing intra-cranial suppuration.

usually falls from a height or blows received from falling bodies or in personal encounters.

The fractures of the vault are for the most part *direct*, that is, the bone is broken at the point where the blow is received; fractures of the base may be *indirect*, or by transmitted violence, or may be due to the extension of a direct fracture of the vault. Some fractures of the base are caused by falls from a height upon the feet, knees, or buttocks, the force being transmitted to the base of the skull through the vertebral column, and in some exceptional cases of falls upon the head the fracturing force is the momentum of the body impinging directly upon the base of the skull at the occipito-atloid articulation and crushing the bone as between a hammer and anvil. The term *fracture by contre-coup* has been much employed in the sense of "indirect fracture," the use originating apparently in an erroneous view of the mechanism by which the injury is produced. It was supposed that, the skull being globular in form and elastic in structure, a blow received at any given point of its surface might be so transmitted as to exert a fracturing force at the opposite or at some intermediate point. This view was supported by the fact that blows upon the head often cause extravasations of blood at distant points within it; but it has been recently shown by Duret[1] that the mechanism of these extravasations is entirely different from that to which it was formerly attributed. He showed by well-devised experiments that when a violent blow is received upon the vault of the skull, with or without fracture, the sudden depression of the bone causes a wave of cerebro-spinal liquid to pass from the point that is struck and from the ventricles of the brain to the base, and this wave causes rupture of the meningeal and cerebral vessels by distension of the meshes of the pia mater and arachnoid during its passage and by the sudden diminution of the extra-vascular pressure which follows its subsidence. By some surgeons the term fracture by contre-coup is applied only to cases in which the fracture occurs at a point diametrically opposite to that at which the blow is received; by others its use is extended to those cases also in which the fracture is at any intermediate point; and by others again, according to Duplay, to cases in which the head, being driven by the blow against some solid body, is fractured at the point which receives the second impact. This last use is clearly unjustifiable, for the fracture is a direct one. It is denied by some authors that cases of the first kind can exist, but, in view of two facts mentioned by Legouest and Servier,[2] I think the possibility must be admitted. These two facts were a fracture of the frontal bone produced by Perrin by throwing a skull forcibly upon its occiput, and a limited fracture of the occipital bone caused by a fall upon the anterior portion of the vertex. In the latter case the patient died in a few hours, the point that received the blow was recognized by the contusion, there was no fracture under it and no fissure connecting it with the fracture of the occipital.

The structure and form of the skull have a marked influence upon the

[1] Etudes expérimentales et cliniques sur les traumatismes cérébraux, vol. i. Paris, 1878.

[2] Dict. Encyclopédique des Sciences Médicales, art. Crâne, p. 598.

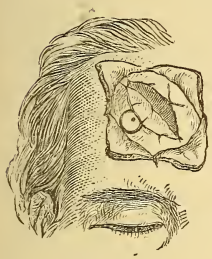
character and extent of a fracture. In accordance with its variations in thickness and with the relations of some of its parts to other bones some portions are more easily broken than others, and lines of fracture beginning at given points on the vault and extending to the base usually follow corresponding lines quite closely. The bone itself is composed of an outer and inner table separated by the softer and vascular diploë and differing in thickness and brittleness, the inner table being the thinner and more brittle. At the lower portion of the frontal bone are found the frontal sinuses, irregular cavities of variable size which appear during childhood and increase in size through adult life. They are situated between the two tables of the bone, and sometimes extend as high as to the frontal eminences and outwards over almost the whole of the orbit. Their importance in connection with fractures lies in the separation between the two tables by which a fracture of the outer without injury to the inner one is rendered easy. The thickest portions of the vault are at the base of the frontal bone, the mastoid region, and the occipital tuberosity; the thinnest at the squamous portion of the temporal and the inferior fossæ of the occipital. Fractures of the vault are produced by direct violence; fractures of the base by the extension of fissures from the vault, by the direct impact of the vertebral column, by force transmitted through the bones of the face, and occasionally by direct violence as in gunshot wounds or in blows with a pointed weapon traversing the orbit, nostril, or mouth.

Pathological Anatomy.—This division into fractures of the vault, of the base, and of both is practically of great importance, since they differ materially in their gravity, and the former alone offer an opportunity for direct surgical interference.

Fractures of the Vault.—With few and rare exceptions, the possibility of which has been admitted, fractures of the vault of the skull are produced only by direct violence, the fracture taking place at the point where the blow is received, and consisting either of a simple fissure or of comminution, and either with or without accompanying depression. A fissure is usually of considerable length, and may involve more than one bone, crossing a suture. Its sides are usually in contact, but may be separated by a slight interval if the fissure is long. Comminution is the result, usually, of a blow with a blunt instrument delivered with much violence, and is seldom accompanied by fissures extending to any considerable distance. When such a fracture is extensive the affected area commonly presents an irregular, funnel-shaped depression, the sides of which are formed by the fragments which remain in contact along the periphery with the undepressed portion and slope inwards to the centre (fig. 125), which lies at a distance below its normal level, varying from a few lines to an inch or more; or the fragments may be driven bodily inwards and entirely separated at the borders from the solid portion, or the depressed portion may consist of two principal pieces sloping inwards to a central line of greatest depression (fig. 126), one of them, perhaps, overriding the other. The inner table is always more extensively fractured than the outer, except when the fracture is produced from within outwards, as by a bullet, in which case the outer table is the one most injured (fig. 127). This peculiarity has been attributed to the greater

brittleness of the inner table, but it is due to mechanical causes, and is similar to what is seen after fracture of other substances. The dura mater is usually torn, but rarely to an extent at all comparable with that of the aggregated lines of fracture.

Fig. 126.



Compound depressed fractures of the skull.

Fig. 125.

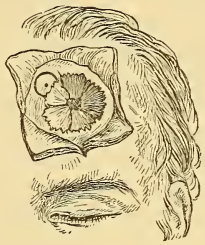
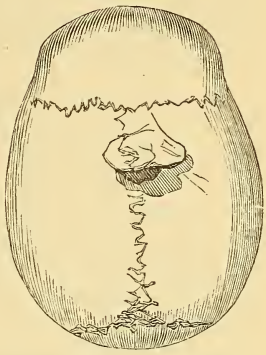


Fig. 127.



Fracture of the skull from within

In exceptional cases the bone, or at least its outer table, is raised above its normal level instead of being depressed. Mr. Hewett[1] says two such specimens are preserved in the museum of St. George's Hospital; in each a fragment involving the entire thickness of the bone is bent outward or raised up like the lid of a box, remaining attached to the skull along the border which forms the angle. The injury was caused in one case by a falling chisel, and in the other by a fall upon an iron railing, one of the spikes of which penetrated the skull. A similar case came under my observation at Bellevue Hospital; the patient was struck upon the back of the head with a chisel, one corner of which traversed the bone, splintering the inner table, and turning up the outer table along the edge of the incision. The mechanism is readily understood: after the instrument has penetrated the bone its direction is slightly changed, and it acts as a lever, prying out the bone on one side instead of forcing it in on the other.

Permanent traumatic depression of the bone without fracture in the adult is unknown and inconceivable. It has been shown by experiment that the elasticity of the skull is such that a point upon its surface can be depressed one-third of an inch without fracture, but the elasticity which permits this prevents the depression from persisting after the removal of the force which produced it. It is possible, perhaps, in the softer and more pliable bones of the infant, but even there it is doubtless associated with partial rupture of the tissue.

The term *incomplete* is applied to fractures involving only one of the tables. They are of rare occurrence, but unquestionable examples of each variety have been recorded, and cases of extensive splintering of the inner table, with only slight injury of the outer table, are not uncommon. Fracture of the outer table alone may easily occur at the

[1] Holmes's System of Surg., Am. ed., vol. i. p. 618.

frontal sinuses, but is rarely met with elsewhere, although it is possible wherever the diploë is thick and soft. I observed a case at the Presbyterian Hospital in 1881; the patient, a man twenty-one years old, had fallen from a considerable height, striking upon his head. The bone, which was freely exposed through two large scalp wounds at the vertex, presented two long fissures, one parallel to and half an inch to the left of the sagittal suture, the other posterior to and nearly at right angles to the former, along the middle of the left parietal bone. I applied the trephine at the centre of each fissure, removing only the outer table in the second one, and enlarging the opening with bone-pliers along the fissure until it measured about an inch in length; the exposed inner table was carefully examined and showed no trace of a fissure. The patient made a rapid recovery.

Fractures of the inner table alone are rare, but have been demonstrated both by operation and by autopsical examination. The greater brittleness of the inner table seems to be entirely foreign to this limitation of the injury, the cause of which lies solely in the direction of the fracturing force. Legouest and Servier refer to a specimen preserved in the museum of Guy's Hospital, which shows a fracture of the external table alone caused by a force acting from within the skull, and is, in their judgment, a conclusive proof of the correctness of this opinion. Additional arguments in its favor and in opposition to the other view, which was formerly held very generally, are furnished, as was first shown by Mr. Teevan, by the study of the mechanism of fracture of any homogeneous tissue, and by observation of the manner in which a thin plate of ice yields under a slowly acting fracturing force.

Mr. Hewett says that if a fracture of the vault is accompanied by a wound of the integument the fracture is much more frequently limited strictly to the seat of the blow than in cases of simple fracture. In twenty cases of compound fracture this limitation existed eight times, while in fifty-six cases of simple fracture it existed only once.

Fractures of the Base.—The base of the skull differs from the vault by the irregularity of its form, the lack of homogeneousness in its structure, the great variations in its thickness, and the presence of many foramina. Viewed from within, it presents on each side three fossæ at different levels, the highest in front, the anterior, middle, and posterior. Of these, the middle one is formed mainly by the temporal bone, and is the one most frequently fractured, apparently because of its position in the line in which blows are most frequently received. The inferior borders of the parietal bones are bevelled on the outer side and fit within the temporals, so that a downward force exerted upon the parietals at or near the sagittal suture and tending to spread them outwards is counteracted by the temporals which act as buttresses or as chords to the arc. In addition to this strain the temporals are subjected also to the crushing one produced by the action of the blow upon the vertex and the resistance offered by the vertebral column, between which two points they are interposed.

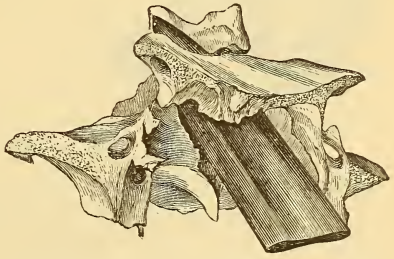
In general terms it may be said the provision against fracture of the base by indirect violence is made by thick ridges radiating from the occipital condyles, while the intermediate portions, being thus relieved

from the necessity of supporting the strain, are left comparatively thin and weak. This arrangement is analogous to that found in other parts of the skeleton, and is in accordance with the general principle observed throughout of combining the maximum of strength with the minimum of weight. While thus protecting the brain from those forms of violence to which it is most frequently exposed, this arrangement, however, leaves it comparatively unprotected against others to which it is occasionally, but much more rarely subjected, that is, against those which tend to produce direct fracture.

Fractures of the base may be *direct* or *indirect*. Direct fractures are rare, and usually the result of gunshot wounds, but there are not a few recorded cases of fracture produced by comparatively slight direct pressure upon the thin portions of the base, such as the roof of the orbit, the horizontal plate of the ethmoid bone, or the sphenoid, exerted by such things as a cane, a foil, a tobacco pipe thrust into the orbit or the nostril.

The orbit is the most frequent channel through which this injury is received, and the cases are remarkable for the slight degree of violence which was sufficient to produce the fracture and for the apparent absence or the unimportant character of the external wound, in one case only an apparently slight scratch upon the eyelid, in another a wound of the conjunctiva undiscovered during life, the weapon having passed between the lids. In a case reported by Pamard[1] the point of a foil passed between the eye and the inner wall of the orbit, broke the plate of the ethmoid, entered the cavity of the cranium by the inner wall of the sphenoidal fissure, and fractured the posterior clinoid process. In another case a testy old gentleman, irritated by some one behind him, made a backward thrust with an umbrella and drove it through the orbit of his tormentor into the brain; in another,[2] a soldier fencing with a comrade with canes received a thrust in his left nostril. He died a few days afterwards with cerebral symptoms, and at the autopsy the ferrule was found lying beside the sella turcica, the body of the sphenoid having been perforated by the cane, and the posterior clinoid process broken off. A similar case (fig. 128) is reported in the first volume, page 337, Surgical History of the War of the Rebellion.

Fig. 128.



Fracture of the clinoid process by a sword-thrust. (U. S. Surg. Hist.)

Direct fracture of the basilar process has been caused by the discharge of a pistol into the mouth with suicidal intent; and, finally, may be mentioned Harlow's unique and very remarkable case reported by Bigelow[3] of a tamping-iron $3\frac{1}{2}$ feet long, $1\frac{1}{4}$ inches in diameter, and weighing $13\frac{1}{4}$ pounds which was driven by the premature explosion of a blast directly through a man's skull, entering the cheek by the angle of the lower jaw, and passing

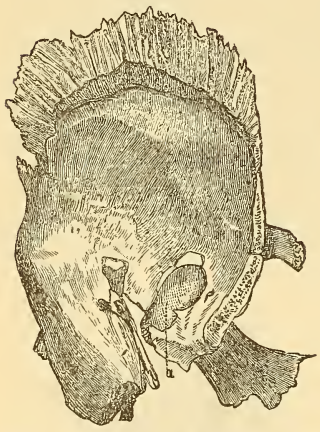
[1] Gazette Hebdomadaire, 1865, p. 455.
[2] Dublin Medical Journal, 1851, vol. i. p. 347.
[3] Am. Journal Med. Sciences, July, 1850.

entirely through and out at the centre of the frontal bone near the sagittal suture. The patient recovered without paralysis or intellectual trouble, but with the loss of sight in the eye of the injured side.

Fracture of the squamous portion of the temporal bone has also been produced occasionally by a blow upon the chin driving the condyle of the lower jaw through into the cavity of the skull, and Mr. Jordan Lloyd[1] reports two cases of fracture of the external auditory process (on both sides in one case) by violence received upon the chin. The diagnosis was made by bleeding from the ear and by recognition of an irregularity in the wall of the canal at the part corresponding to the condyle of the jaw. Neither the cavity of the cranium nor the temporo-maxillary joint appeared to have been opened. This variety is classed by some among the indirect fractures, but although, strictly speaking, it comes under the definition of that term, it is certainly identical in its mechanism with the direct fractures above described.

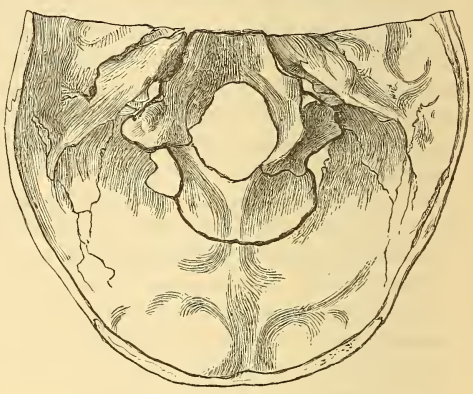
The same remark and comment may be made concerning those very rare fractures limited to the neighborhood of the foramen magnum and produced by a fall upon the head, the momentum of the body supplying the force which is transmitted directly to the occipital condyles by the atlas (fig. 130). Duplay[2] quotes from Chauvel one case of death fol-

Fig. 129.



Perforation of the skull by the condyle of the jaw.

Fig. 130.



Fracture of the base by a fall upon the vertex.

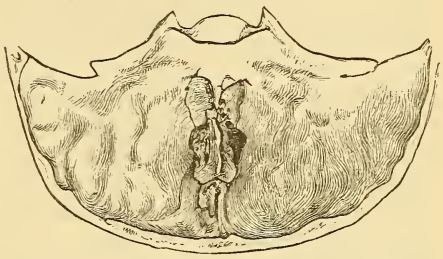
lowing a fall upon the head, in which the autopsy disclosed an elliptical fracture surrounding the foramen magnum and circumscribing the centre of the base of the skull which had manifestly been driven in. The rest of the skull was intact. The same surgeon produced experimentally an analogous double fracture occupying the occipital bone alone and extending in two lines three and five centimetres long from the posterior foramina lacera into the inferior occipital fossæ. The cadaver was that of a man 63 years old with complete bony fusion of the first six cervical vertebræ.

[1] British Med. Journal, 1882, vol. i. p. 190.
[2] Pathologie externe, vol. iii. p. 467.

And Sir Charles Bell[1] reports the case of a young man brought to the Middlesex Hospital after a fall upon the head; he presented no important symptoms, and was soon discharged. As he left the hospital he fell dead, and the autopsy showed fracture of the borders of the occipital foramen. It was thought that the fragments had suddenly become displaced and had compressed the medulla.

Other indirect fractures have been produced by falls or blows upon the face, the ethmoid being driven in by a blow upon the nose (fig. 131) and the orbital plate of the frontal by a blow upon the anterior portion of this bone. A case which is almost unique is mentioned by Sappey;[2] transverse fracture of the body of the sphenoid produced by a fall from a wagon. The patient survived eight months, death being due to an arterio-venous aneurism originating in a rupture of the carotid artery within the cavernous sinus at the time of the accident. Legouest and Servier state that a somewhat similar fracture was produced experimentally by Perrin, and that a specimen of a third is now in the Musée Dupuytren.

Fig. 131.



Fracture of the base by a blow on the nose. (Bryant.)

Felizet[3] asserts that in fractures of the base the region of the basilar process has remained uninjured between the foramen magnum and the sphenoid.

The great majority of fractures of the base of the skull are, however, produced by the extension of fractures originating in the vault, and for the correct appreciation of this origin we are mainly indebted to the labors of Dr. Aran,[4] who made a thorough experimental and clinical study of the subject. His experiments were made by letting cadavers fall from a height or by striking the skull with a large heavy hammer, and he summarized his results in the three following sentences: 1st. In no experiment was a fracture of the base produced without fracture at the point that received the blow; 2d. Fractures of the vault usually radiate to the base, and are not arrested by the sutures; 3d. They take the shortest route to the base, following the curves of smallest radius.

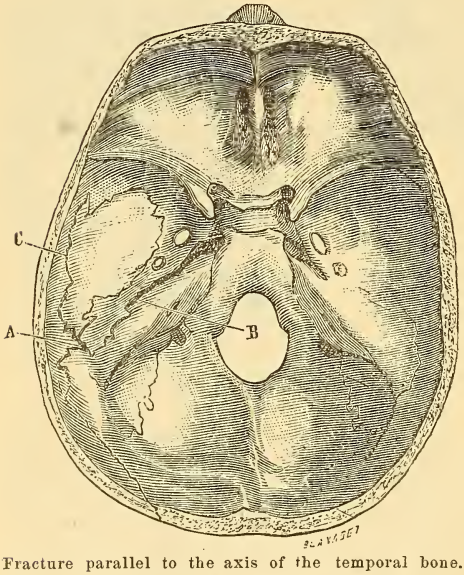
Fractures of this kind show a fissure at the point struck, usually a slight one, which enlarges towards the base and may extend in various directions, but, as a rule, follow certain definite lines determined by the region which receives the blow. Thus, a blow upon the front of the vault causes fracture of the base in the anterior fossa; a blow upon the parieto-temporal region causes fracture of the middle fossa, and one upon the occipital bone produces lines of fracture extending towards the foramen magnum. Prescott Hewett[5] found these statements fully verified by ex-

[1] Surgical Observations, London, 1816.
[2] Anatomie descriptive, 2d ed., vol. i. p. 191.
[3] Recherches sur les fractures du Crâne, Paris, 1873.
[4] Archives Gén. de Médecine, 1844, 4th ser., vol. vi. p. 180.
[5] Holmes's System of Surgery, Am. ed., vol. i. p. 627.

amination of the cases of fracture of the base of the skull admitted into St. George's Hospital during a period of ten years. He divided the skull into three zones or segments. "An anterior zone formed by the frontal, the upper part of the ethmoid, and the fronto-sphenoid; a middle zone, by the parietals, the squamous and the anterior surface of the petrous portion of the temporals, with the greater part of the basi-sphenoid; and a posterior zone, including the occipital, the mastoid, and the posterior surface of the petrous portions of the temporals, with a small part of the body of the sphenoid." In the less severe cases the line of fracture was strictly limited to one of these zones; of 25 cases it was limited to the anterior zone in 5, to the middle zone in 14, and to the posterior zone in 6. In the more severe cases it spreads into two or even into all three zones; out of 29 such cases the middle and anterior zones were involved in 14, the middle and posterior in 15. In 10 cases all three zones were implicated. This analysis shows the great frequency with which the middle fossa is involved, for of the total of 64 cases it was broken in 53. Mr. Hewett adds that in the severer injuries there may be in addition small circumscribed fractures having no connection with the main line of fracture. Thus, the roof of the orbit or the posterior clinoid processes may be broken independently.

Duplay calls attention to the fact that the fracture is sometimes parallel, sometimes perpendicular, and sometimes oblique to the axis of the petrous portion of the temporal bone. The parallel fractures (fig. 132) pass in front, or at the level, of the external auditory foramen and end at the foramen lacerum anterius, dividing the petrous portion into two unequal parts of which the smaller, the anterior one, contains only a portion of the external auditory canal and of the middle ear. The perpendicular fractures are the most rare, and pass just outside of the internal auditory foramen, involving both the vestibulum and the labyrinth. The oblique fractures, which are much rarer than the parallel but more common than the perpendicular ones, are situated near the base of the petrous portion, run downwards and inwards parallel to the tympanum, and divide the middle ear. Duplay claims that the parallel fractures result almost invariably from a blow upon the temporal region, the others from a blow upon the occiput.

Fig. 132.



Fracture parallel to the axis of the temporal bone. (Follin and Duplay.)

Finally may be mentioned those extensive fractures due to extreme

violence in which all or nearly all the bones are shattered, the sutures separated, and the fragments displaced and movable.

It occasionally happens in fractures both of the vault and base, that a venous sinus may be injured, and if the fracture is a compound one the injury may be followed by severe hemorrhage, which, however, is rarely fatal.

The important practical pathological point in the great majority of all fractures of the skull is the degree and character of the associated injury to the brain and its coverings, and in this must be included not only the immediate lesions produced at the moment the injury is received, but also the more remote consequences following a permanent change in the inner surface of the skull by fragmentation or depression, or by overgrowth of callus.

Symptoms and Diagnosis.—The symptoms following an accident which has caused a fracture of the skull vary greatly with the part involved, and the most prominent ones are often those due to the associated lesions of the brain and meninges, the detailed consideration of which does not lie within the scope of this subject. The symptoms of the fractures may be best presented by following the division adopted in the preceding paragraphs, and grouping them as those of *fractures of the vault* and *fractures of the base.*

1. *Fractures of the Vault.*—The positive physical signs of fracture are depression of the surface of the bone, which may be recognized through the integuments when the fracture is simple, and the existence of a fissure, comminution, or depression recognizable by the eye or finger when the fracture is compound. In the case of a simple fracture the diagnosis is often difficult and sometimes impossible, for not only is a fissure unrecognizable by the touch, but even a moderate depression may escape detection, especially when covered by thick muscles, as in the temporal region, or leave the surgeon in doubt because of the difficulty of distinguishing between it and an inflammatory swelling, or an extravasation of blood under the scalp which often gives to the finger the sensation of a soft, depressible centre with a firm, hard, circular border. Or a congenital depression or senile thinning of the bone may be mistaken for the result of a recent traumatism. Duplay cites the case of a man who had been rendered unconscious by a fall from the third story of a house ; the surgeon found a broad deep depression of the skull over which the skin had not been bruised, and prepared to cut down upon it, but fortunately the patient recovered consciousness in time to escape the exploration by informing him that the depression was not the consequence of the fall, but had existed from childhood. Similar cases have been reported by others.

When, on the other hand, the bone has been exposed, there is no difficulty in recognizing a fracture, or even a fissure in the wound, and no objection to enlarging the wound, and even scraping up the periosteum if there is reason to suspect the existence of fracture in the immediate neighborhood. Error in such a case has arisen by mistaking a suture for a linear fracture, but it is one which should be readily avoided if the possibility is borne in mind, even if the suture deviates from its normal position or is that of a Wormian bone.

A very positive sign of fracture is the escape of brain tissue through the wound, or of the cerebral liquid through the wound or under the unbroken skin. Mr. Hewett mentions a case in which the inspissated secretion of a frontal sinus was mistaken for brain substance.

Fracture of the inner table alone may be suspected from the character of the violence, its existence being considered more probable when the involved area is limited in extent, as in punctured wounds or blows with a pointed object such as a nail or spike, or from the later symptoms of intra-cranial suppuration, but the diagnosis can never be made positively. Its symptoms, physical and rational, are solely those of traumatic meningitis or cerebritis, and are, therefore, not to be distinguished from those following traumatic extravasation of blood upon the surface of the brain without fracture.

The presence of a fissure upon the surface is not a proof that both tables are broken, although it makes it extremely probable, and an intermittent flow of venous blood from it corresponding in its intermittences with the respiratory acts, that is, increasing during expiration, and diminishing or ceasing during inspiration, is not a proof that the blood comes either from the meningeal vessels or a venous sinus, for when it comes only from the diploë near a sinus it may present this character, as I observed in the case above mentioned of fracture of the external table alone.

The rational signs are, for the reason already stated, of but little value in the diagnosis when the physical signs are in default. The probability of a fracture may be strengthened by the character of the violence which caused the injury, and, in exceptional cases, by a sign mentioned by some authors, a sound like that of a cracked pot heard at the moment of the accident by persons standing near the patient. Duplay says this sound is often heard in experimenting upon the cadaver, and always coincides with the production of a fracture. The presence of a localized pain in the head, indicated when the patient is unconscious by repeated movements of the hand towards the affected point, is mentioned as a probable sign by some writers, but certainly is not sufficient to establish the diagnosis. Œdema of the scalp when there is no open wound, and persistence of suppuration when there is one, have been long regarded as probable signs, but are too indefinite to be at all trustworthy.

Haward[1] reported a symptom which is probably very exceptional, but which, if it occurs and is fairly recognized, is pathognomonic ; the appearance under the scalp of a translucent, pulsating swelling due to the escape of the cerebro-spinal liquid. In Haward's case the patient was a child 19 months old ; the tumor appeared over the right frontal bone after a fall upon the head, increased for ten weeks, and ruptured spontaneously through the conjunctiva eight days after eight ounces of liquid had been removed by tapping. A large quantity of liquid escaped through the rupture, and it continued to flow during the three days the child survived. The autopsy, which was restricted to the seat of the fracture, showed a depression of the right frontal bone and a fracture of

[1] Lancet, July 17, 1869, p. 79.

the arch of the orbit through which the handle of a scalpel could be easily passed into the brain.

Mr. Hewett[1] gives eight additional cases of the escape of a clear serous liquid after compound fracture of the vault and two after trephining for epilepsy, the discharge beginning in some immediately after the injury, in others not until after the lapse of several days. Of the 11 cases 8 recovered. In some of the cases the liquid came evidently from the lateral ventricle, either through a wound of the overlying substance of the brain or by distension and rupture, in others from the subarachnoid space. The discharge does not seem to affect the prognosis unfavorably, except so far as it may be due to associated injury to the brain.

2. *Fractures of the Base.*—It is only in very rare and exceptional cases, some compound fractures of the more accessible portions, that fractures of the base present positive physical signs that can be recognized by the eye or finger. The symptoms that must ordinarily be depended upon for making the diagnosis, if we except the probabilities arising from the nature of the injury and the associated cerebral disturbances, are the escape of the contents of the cranium, blood, cerebro-spinal liquid, or brain substance, through the natural openings or a wound, and paralysis of one or more of the cranial nerves.

Bleeding from the mouth, nose, or ears follows certain fractures of the anterior and middle fossæ in which a communication has been established between an intra-cranial bloodvessel, usually a venous sinus, and the cavity of one of these organs. In many fractures, however, even in extensive ones, such a communication is not established, and then the symptom is absent.

"Bleeding from the ears in severe injuries of the head," says Mr. Hewett, "has for many years past been held, and deservedly too, as one of the most valuable diagnostic signs of fractured base. But the bleeding, to be of any real value as a means of diagnosis, must be of a serious nature, and, above all, it must continue for some time. With such a bleeding it may be safely diagnosed that there is a fracture of the base running through the petrous bone and opening up a communication between the cavity of the tympanum and some of the numerous and large vascular channels which surround this bone, or with an extravasation of blood within the cranium itself." He found that out of 32 cases of fracture of the base implicating the petrous portion of the temporal bone the bleeding from the ear was profuse and continuous in 15; in 12 of the remaining cases the line of fracture did not extend into the tympanum, and in 5 the tympanum was fractured but the membrana tympani was not ruptured. In more than half the cases, therefore, this sign was absent, but when present its diagnostic value was great. Nevertheless it is not absolutely pathognomonic, for there are quite a number of recorded cases in which an abundant hemorrhage from the ear has followed a severe injury to the head which has left the base of the skull unbroken. It follows occasionally fracture limited to the mastoid process, and Duplay reports a case in which it was due solely to rupture of the membrana tympani.

[1] Loc. cit., p. 634.

Hemorrhage from the mouth or nose, or vomited blood, has less diagnostic importance than that from the ears. The blood comes in some cases from the nose or mouth after fracture of the petrous bone, making its way through the cavity of the tympanum and the Eustachian tube, and if the membrana tympani is ruptured it may escape at the same time through the ear. Here too the profuseness and continuance of the bleeding are a more valuable sign than the mere fact of the hemorrhage, for the vascularity of the mucous membrane lining these cavities is such that bleeding from it readily follows trifling injuries. Of the 32 cases of fracture of the base implicating the central bones of this region analyzed by Mr. Hewett, bleeding from the nose or mouth, or subsequent vomiting of blood occurred in 14 with symptoms giving rise to the belief that the fracture involved some of the bones corresponding to the pharynx or nose; and dissection showed that in 4 of them the fracture was confined to the ethmoid, in 3 to the body of the sphenoid, and in 1 to the basilar process. In 5 both the ethmoid and sphenoid were fractured, and 1 the basilar process also.

Extravasations of blood under the unbroken skin, ecchymoses, have a similar diagnostic value for the same reasons, when they are found in certain locations and are not due to a local contusion of the soft parts. Of these the most common and most important in some respects is effusion into the orbit, due to fracture of the orbital plate of the frontal and of the sphenoid with rupture of the ophthalmic artery or of a venous sinus. The blood makes its way forward and appears first under the ocular conjunctiva, then under that of the lids, and finally, after the lapse of some time, under the cutaneous surface of one or both lids. The diagnostic value of the symptoms is greatest when the blow has not fallen upon the head near the eyes, when the blood makes its appearance at the different points in the order just mentioned, and when the ecchymosis is of considerable size. Usually the lower lid is affected earlier and to a greater extent than the upper one, but Mr. Hewett says he has seen two cases in which the ecchymosis was confined to the upper lid.

Out of 23 cases of fracture of the base involving the orbital plates of the frontal bones, collected by Mr. Hewett, the nature of the injury was made manifest in 10 by this symptom; in 8 cases there was no ecchymosis, either in the lids or under the conjunctiva, and in 5 the effused blood appeared in the eyelids alone.

A possible source of error in making a diagnosis of fracture of the base upon this symptom lies in the fact that blood may, although rarely, be effused into the lids or under the conjunctiva after fracture of the malar or superior maxillary bone.

A symptom that has its origin in a similar condition is the formation of so-called orbital aneurism, which is most common when the carotid artery is ruptured within the cavernous sinus, but may also follow rupture of the ophthalmic artery. In a few cases a bruit was heard within the head immediately, or within a very short time, after the accident, and the usual symptoms of protrusion of the eyeball and dilatation of the orbital and frontal veins followed in due time. A somewhat similar protrusion of the eyeball unaccompanied by a bruit and dilatation of the veins has been caused by an effusion of blood into the posterior portion

of the orbit. And Mr. Hewett refers to three cases in which a traumatic aneurism, apparently not an aneurism by anastomosis, in the back of the orbit was caused by fracture of the base.

Ecchymosis in the pharynx is rarer and of less value in the diagnosis; Dolbeau is mentioned by Duplay as having reported some cases, the effusion taking place into the retro-pharyngeal cellular tissue and causing ecchymosis and difficulty in deglutition.

Ecchymosis of the mastoid region or of the side of the neck, appearing some time after the receipt of an injury, especially if the latter has taken place upon the opposite side of the head, has some diagnostic value, and Mr. Hewett says that sudden puffiness in the occipital region with ecchymosis some hours after a severe injury to this portion of the head may also be of use in making the diagnosis of fracture of the base. The blood comes from the adjoining venous sinuses, and gradually oozes through the fracture and makes its way to the surface.

A watery discharge from the ear or nose, similar to that mentioned in connection with fractures of the vault, is occasionally observed after fracture of the base. It occurs more frequently from the ear than from the nose, and is then indicative to a certain degree of fracture of the petrous portion of the temporal bone.

A watery discharge from the ear after fracture of the base is said by Duplay to have been vaguely indicated for the first time by Bérenger de Carpi, and to have been described with more detail in 1728 by Stalpartius Van der Weil, who had observed one case and quoted another. Mr. Hewett says that O'Halloran published some thirty years later another and even more characteristic case, but adds, that the subject, although known to at least one other writer, appears to have been lost sight of until 1839 when Laugier[1] first pointed out the connection between this discharge from the ear and fracture of the petrous portion of the temporal bone together with rupture of the membrana tympani.

Various origins have been ascribed to this discharge, and it has now been proved by numerous analyses and dissections that its source is not always the same, and that consequently it is not so certain a sign of fracture of the base as has been believed and taught in the past.

(1) Chemical analysis of the liquid in some cases showed that it contained a large amount of chloride of sodium and but little albumen, thus resembling the cerebro-spinal liquid; and dissections have shown the presence of the lesions necessary to permit the escape of this liquid from the cranium, that is, fracture of the internal auditory canal extending into the tympanum, rupture of the membrana tympani, and laceration of the portion of the arachnoid which accompanies the seventh nerve into its foramen of exit. On the other hand, it must be admitted, all these three lesions have been found in cases in which this symptom was lacking. The facts already mentioned of profuse watery discharge after fractures of the vault, in which the liquid unquestionably came from the sub-arachnoid space or lateral ventricles, lend additional support to the theory of this origin, if any is needed.

(2) Fedi, quoted by Duplay, published a case in which the discharge

[1] Comptes Rendus de l'Académie des Sciences, 1839, p. 240.

from the ear lasted about thirty-four hours, and was estimated at nearly three ounces, but in which the autopsy showed no lesion except a fracture of the base of the stapes establishing a communication between the labyrinth and the cavity of the tympanum. (The membrana tympani must also have been ruptured or destroyed, but this is not mentioned.) In this case the liquid must have been the liquor Cotunnii, and its amount can be accounted for only on the supposition that the membrane lining the labyrinth continued to secrete it as it escaped.

Mr. Hewett says there are many such cases in which dissection has shown that the fracture did not involve the meatus auditorius internus, but passed through the internal and middle ear without touching the meatus.

(3) There are cases in which a profuse watery discharge from the ear has followed injury to the head, in which there was no fracture involving the internal or middle ear, and no communication between them. Hewett quotes two such cases, one dissected by Mr. Henry Gray and himself, and reported in the *Transactions of the Pathological Society of London*, vol. vi. p. 22, the other by Mr. Holmes; and Duplay quotes a third reported by Ferri in the *Gazette Hebdomadaire*, vol. i. p. 59.

In Mr. Hewett's case the patient was brought to the hospital, after a fall from a ladder about twenty feet high, with bleeding from the left ear and a scalp wound on the upper and back part of the head. The next day the discharge was pink and flowing at the rate of two ounces per hour. This flow continued for two days, then became much less, and on the sixth day was scanty and puriform. The patient died on the seventh day with diffuse cellular inflammation of the scalp, and brain symptoms. The autopsy showed entire absence of fracture or any injury of the temporal bone, and of communication between the internal and middle ear; but the membrana tympani was ruptured and the lining membrane of the tympanum internally congested and covered with a muco-purulent secretion.

In Mr. Holmes's case the patient was admitted with bleeding from the ear, which was followed by a copious watery discharge. The autopsy showed no fracture of the temporal bone, and no injury in the cavity of the tympanum or the internal ear. The lower jaw was broken just below the condyle, and the lower fragment had perforated the wall of the external auditory canal.

In Ferri's case there was a watery discharge of sixty-three ounces in one hundred and six hours. The patient died six years afterwards of caries of the temporal bone of the opposite side, and at the autopsy there could be found no trace of fracture upon the side from which the discharge had taken place, but only a cicatrix of the membrana tympani and the signs of past inflammation of the cavity.

It thus appears that although a profuse watery discharge from the ear is much more commonly associated with fracture of the temporal bone than with any other injury, yet it is not absolutely pathognomonic of that lesion, and its diagnostic value is only that of a *probable* symptom. This value is, moreover, affected by the circumstances of the appearance and character of the discharge. Thus, if the discharge appears promptly after the receipt of the injury, if it is distinctly watery

and is preceded by little or no bleeding, if it is abundant, one or two drachms in the hour, and if it is modified by change in the position of the head, by coughing or sneezing, the diagnosis may be considered positive. If, as happens in a second class of cases, an abundant and prolonged hemorrhage precedes the watery discharge the diagnosis of fracture of the base is still reasonably certain, but it is based, not on the watery flow, but on the bleeding, which has its probable origin in fracture of the petrous portion. There is, however, a third class of cases in which the preliminary bleeding is neither abundant nor prolonged, and the watery discharge varies in the time of its appearance and in its quantity, perhaps appearing soon after the accident, or being profuse for a short time; in these the diagnosis is doubtful, whether based on bleeding or on the watery discharge.

Mr. Hewett says that while it has been taught by some surgeons that a profuse watery discharge after an injury to the head occurs most commonly in childhood and youth, the cases which have come under his own observation have been for the most part more than thirty years of age.

The symptom has long been considered a very serious, even a fatal, one ; but that the case is not hopeless, even when the diagnosis of fracture of the base is as certain as it can be under the circumstances, is proved by the recoveries which have been recorded. One such recovery and one probable recovery have come under my own observation; in both cases the discharge was watery, profuse, and continuous, with loss of hearing in the affected ear; and in each the injury was caused by a violent fall. One case recovered entirely, the other passed from observation a week after the accident, but he was then doing well, and the discharge had ceased. Still, it is to be regretted that a chemical analysis of the liquid has not been made in the cases that have recovered, in order that the accuracy of the diagnosis might be comfirmed by all possible means.

A similar profuse watery discharge from the nose has been observed, but much more rarely than from the ear. It presented the same chemical composition as the cerebro-spinal liquid, that is, it contained a large quantity of chloride of sodium, and but little or no albumen, and in one case, Roberts,[1] the autopsy showed a fracture (pistol-shot) of the sella turcica and laceration of the arachnoid and pituitary body. The liquid flowed freely when the body was turned upon its face ; and water poured upon the seat of the fracture within the skull ran out through the nose. It is, therefore, a reasonable assumption that the flow observed during life came from the large sub-arachnoid spaces underlying the brain, and also, perhaps, from the ventricles through the infundibulum and torn pituitary body. In other cases reported by Foucart and Malgaigne (quoted by Hewett), the temporal bone was fractured and the discharge reached the nose through the middle ear and the Eustachian tube.

A possible source of error lies in the copious clear secretion which is sometimes poured out by the nasal mucous membrane under the influence of even a slight irritation.

[1] Archives Gén. de Méd. 1845, 4th series, vol. ix. p. 412.

The escape of the substance of the brain through the ear or nostrils has been observed in a few cases of comminuted fracture, but the diagnosis appears to have been plain without the aid of this symptom.

Paralysis of one or more cranial nerves is occasionally observed in connection with fractures of the base, as the result either of direct injury to the nerve in fractures by direct violence, of rupture of the nerve or pressure upon it by one of the fragments when the line of fracture crosses its course, or of pressure by extravasated blood. The nerves most frequently involved are the 7th pair, the optic, and the olfactory; and, according to Mr. Hewett,[1] examples are on record of injury to every pair except the 4th, those of the 8th and 9th being the most rare. He mentions a case of the latter in which the injury to the nerve was caused on the tenth day after the accident, by the displacement of the fragments. The patient was doing well, left his bed on that day, and walked across the ward. He was seized with rigors and vomiting, became unconscious, and died of asphyxia forty-eight hours afterwards with increasing dysphagia and gasping respiration. The autopsy showed no lesion or inflammation of the brain or its membranes; the line of fracture crossed the right foramen lacerum posterius, and the bones there were so displaced that the right cerebellar fossa was lower than the left.

The diagnostic value of the symptom is only accessory, because it may be, and frequently is, due to other lesions than fracture, such as injury to the brain itself, intra-cranial extravasation of blood, and hemorrhage within the sheath of the nerve. Paralysis of the facial nerve, however, has more significance than that of any other.

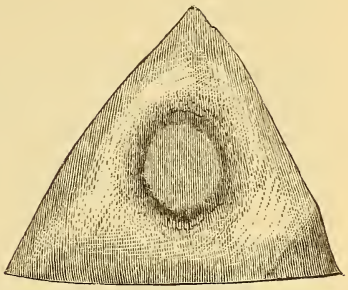
The prognosis after fracture of the skull depends mainly if not entirely upon other factors than those which enter into the prognosis after fracture of a limb. The prognosis *quoad vitam* is grave because of the lesions of the brain or its envelopes which may be associated with the injury or which may arise in the progress of the case. The injury to the bone itself is rarely of a character to leave any disability if the patient survives, although a depressed fragment or an exuberant callus (which is rare) on the inner side may cause epilepsy or loss of mental power, especially if the fracture has occurred during youth. MacEwen[2] has recently given several illustrative cases. Repair takes place as after fracture of the flat bones, described in Chapter VI., that is, the reparative material is furnished mainly by the periosteum and diploë. The result of this is that the fractures are slow to unite, because the diploë is usually scanty, and, as compared with the marrow of the long bones or the spongy tissue of others, is hardly to be taken into account. It was shown in the Chapter on Repair how slowly the compact bone tissue prepares itself to repair a fracture, and as, for some reason which does not appear clearly, the pericranium and dura mater do not seem to form callus readily and abundantly, the labor seems to fall mainly upon the bone itself, and the callus is a small one. When a fragment is depressed and the periosteum stripped up, new bone is formed by the latter as under similar circumstances elsewhere.

[1] Loc. cit., pp. 655 to 659.

[2] Lancet, September, 1881.

Loss of substance, unless very small, is never entirely repaired by bone, but the gap is filled partly by new bone and partly by fibrous tissue (fig. 133).

Fig. 133.



Repair by fibrous tissue after trephining.

Treatment.—Here again we have to distinguish between fractures of the vault and fractures of the base.

Fractures of the Vault.—After Percival Pott had so improved the construction of the trephine as to greatly diminish the chance of wounding the dura mater which was associated with the use of the older instruments, it was held that active interference was called for in the great majority of cases, even when symptoms of cerebral injury or inflammation were not present. Pott[1] asserted that "perforation is absolutely necessary in seven cases out of ten of simple undepressed fracture of the skull," because it was believed that intra-cranial inflammation would almost certainly follow even a simple fissure of the skull. The *trépan préventif*, the use of the trephine simply with the view to prevent intra-cranial inflammation, was indorsed by the Académie de Chirurgie, and all surgeons guided their practice by this theory until the beginning of the present century, when a reaction set in and extended so far that the use of the trephine became very rare, and was thought to be justifiable only after grave cerebral symptoms had made their appearance. Most writers upon surgery during the last twenty or thirty years condemn its use unequivocally except in compound fractures with depression and with marked and persistent cerebral symptoms. It would be easy to multiply citations in support of this assertion; the exceptions to this teaching are rare and seldom go beyond admitting the possible propriety of elevating depressed bone in compound fracture when there are no signs of compression. The influence of this teaching is seen in the following quotation from Bryant:[2] "At Guy's Hospital, trephining and elevation of bone have been performed in 51 cases during seven years, and of these only 12 recovered. At St. Bartholomew's Hospital it was recorded by Callender in 1867 that the operation had not been performed for six years. At University Hospital, Erichsen gives 6 cases of recovery out of 17." I am not aware of the existence of any statistics that show the proportion of recoveries in the cases in which the trephine was not used, and indeed this class of injuries does not readily allow the question of treatment to be decided by tables of percentages. Morgagni's warning, *observationes perpendendæ, non numerandæ sunt*, needs to be regarded here as much as anywhere, and the study of recorded cases shows, I think, that the mortality following the use of the trephine, and upon which its restriction is so largely based, is to be charged not to the operation, but to the lesions whose symptoms finally led to it after a delay that had deprived it of most of its chances of success. I should hesitate to express upon

[1] Injuries of the Head, p. 130.
[2] Practice of Surgery, 3d Am. ed., p. 185.

so important a point an opinion opposed to that of authors whose authority is confirmed by so large an experience, if it were supported only by theoretical considerations, but the periodical publications of the last few years show that its results when carried into practice have been favorable, and I know that it is held and acted upon by many of the profession in New York, in whose knowledge and judgment I have the most confidence. Moreover, so far as my own observation and experience go, the practice of early active interference yields good results, that is, the percentage of success is not only very much greater than that furnished by the tardy use of the trephine, but is actually high, especially when the wound is treated antiseptically. During the last year, 1880–81, thirteen compound fractures of the skull have been treated at Bellevue Hospital by trephining, and under this term I include the use of the bone-pliers to remove a portion of bone so as to elevate or remove the depressed portions. One case was a gunshot fracture, the bullet was buried in the brain and the patient died in twenty-four hours. In another the fracture was overlooked for nearly a fortnight; then severe brain symptoms set in, the wound was enlarged, a slight depression found, and the trephine applied; pus was found between the dura and the bone; the patient died soon afterwards, and the autopsy disclosed a circumscribed suppurative meningitis. Of the remaining 11 two died, eight recovered, and one is still under treatment with hernia cerebri. Seven of these eleven presented no brain symptoms beyond stunning, and were operated upon immediately after the accident; they all recovered, and in two of them the amount of bone removed was about three square inches, one of them being further complicated by a wound of the longitudinal sinus. The remaining four cases presented brain symptoms, they were operated upon immediately, 2 died, 1 recovered, and the fourth is the one with hernia cerebri, just mentioned. Within the same period I have operated at the Presbyterian Hospital upon two cases of compound fracture, one with extensive depression, the other with double linear fracture; both operations were done within two hours after the accident, and both patients recovered without a bad symptom. In contrast to these I may mention two cases that have recently come under my observation, one of the tardy use of the trephine, the other of non-interference; both terminated fatally, the first with suppurative meningitis, the second with abscess of the brain. Both fractures were compound and small, both patients walked to the hospital, and neither presented brain symptoms until after a week had passed. Both, I think, might have been saved by an early operation.

The radical difference between the teachings of a century ago and those of the present time is not to be explained by any important advance in our knowledge, either of surgical science or of the nature of this class of injuries. It is mainly a question of clinical experience: Does delay give better results than early operative interference? And if surgeons during the last fifty years have practically limited their experience to one method of treatment, they are without sufficient means to answer the question, for they know only one side of it, and their opinions must be judged by the aid of such knowledge as can be drawn from

the experience of others, and from the study of the nature of the lesions and of kindred facts.

Curiously enough, the practice of the surgeons of the last century has been followed up to the present time in the mining districts of Cornwall, where fractures of the skull are common, and immediate trephining is the rule; and the results of this practice have been recently given, in general terms, by Mr. Robert Hudson,[1] who bases upon them an appeal for the earlier and more frequent use of the trephine. He quotes Mr. Michell to the effect that a week rarely passed while he was a student without one or two operations, and that he had seen three done in a single day, all in the physician's office, and the patients afterwards walking home. Trephining is so much the rule that the miners expect it even in comparatively slight injuries, and it is not the use of the trephine, but the failure to use it, that requires to be explained to them. Mr. Hudson says the first question of the patient's friends is: "Is his skull broken?" And if that is answered affirmatively, the next is: "When are you going to bore un?"

There is no lack of experience in non-traumatic cases to show that the operation of trephining is not in itself a dangerous one if the dura mater is not divided, and the experiments of Mr. Leo[2] have shown that we may expect the danger to be diminished, if not entirely removed, by the use of the antiseptic method. He trephined 26 monkeys and treated the wounds antiseptically; 19 recovered, and of the 7 deaths only 1 appeared to be due to intracranial inflammation; 4 died in consequence of the extreme cold of the season, 1 from the effects of the chloroform, and 1 from a hemorrhage on the sixth day. All that were trephined and treated without antiseptic precautions died of purulent meningo-encephalitis.

Chadborn trephined Philip of Nassau twenty-seven times for epilepsy; and in another case the operation was performed fifty-two times upon one individual. Trephining for epilepsy, headache, and vertigo is common among the barbarous or semi-civilized peoples of Africa and the Pacific, who submit themselves to it coolly, often twice or three times, and apparently without fear of fatal results. Among the Kabyles the operators have a semi-religious character, and have usually undergone the operation themselves; the instruments are considered sacred, and are handed down from father to son through many generations. Between 1850 and 1870 the operation was done quite frequently in Europe and the United States for the relief of epilepsy, and the later abandonment of the practice, except in cases having a traumatic origin, appears to have been the result rather of its failure to cure the disease than of the mortality that followed it.

The reaction against the use of the trephine appears to have been the result of two causes: the success of non-interference in some cases, and the failure of tardy interference in others. When a case did not present grave brain symptoms at the outset surgeons were encouraged by the former to delay; and when, finally, such symptoms had set in, and

[1] British Medical Journal, July, 1877, vol. ii. p. 75.
[2] Ibid., May 14, 1881.

the patient's chances of recovery were diminished by the complications, the failure of the operation to relieve them bred a disbelief in its power to prevent them, and strengthened the reluctance, which seems to me in this connection to be sentimental rather than surgical, to add to the extent of the existing lesion by operation. The reasoning consists of two propositions and a deduction: 1st, some patients recover without operation; 2d, some die after operation; therefore, it is better not to operate until you are sure the patient will die if you do not. The error, in my judgment, lies in the failure to take into account more positively the influence of the *persistence* of the primary lesions in producing the later symptoms which point to a fatal termination. All agree that the principal danger arises, not from the fracture of the bone, but from inflammation of the brain and its coverings, and admit that a depressed fragment of bone, or even a clot, may excite this inflammation. Why then should we hesitate to increase the extent of the comparatively indifferent lesion of the bone, if the much more important lesion of the brain or the meninges can thereby be lessened or averted? And that it can be thus lessened or averted in many cases there is every reason to believe, on both clinical and theoretical grounds. In the other cases the primary injury of the viscera is so severe that the removal of the fragments will not prevent the development of fatal inflammation. The result seems to depend largely upon the condition of the dura mater; if that is untorn the chances are in favor of recovery.

In compound fractures with depression I think the safest practice is to remove immediately enough bone by means of the trephine, Hey's saw, or bone-pliers, to allow the fragments to be easily elevated or removed, and I think, further, that the surgeon should not be timid about removing the latter freely. Great caution must be used in dealing with fragments that have been driven through the dura mater, in order that the injury to the brain and the meninges may not be increased by the manipulations. Some surgeons even recommend that they should be left until the tissues shall have become somewhat consolidated about them by inflammation, but I should consider a slight increase of the laceration much less of an evil than the additional stimulus given by the presence of the fragment to the inflammatory process, which it is so desirable to keep within narrow bounds. The edges of the opening on the inner surface must be carefully examined and all projecting points removed. Good results have been obtained in two cases[1] by suturing the divided dura mater with catgut.

In compound linear fractures, the question of interference may perhaps be determined by consideration of the character of the violence that caused the injury; if it were severe enough or sufficiently circumscribed to make splintering of the inner table probable, I should apply the trephine and remove at least the outer table so as to explore the inner one. This latter can be easily done in some cases, whenever the diploë is abundant and soft. The removal of a disk of bone entails no serious disability if the patient recovers, and it enables the surgeon to discover and properly treat those complications which experience has

[1] W. T. Bull, in Archives of Medicine, vol. i. 1879, p. 219.

shown to be liable, if not likely, to exist on the under surface, and even if those complications do not exist I believe it to be of advantage by providing a free escape for the discharges from the dura mater and the surface of the fracture itself. The necessity of drainage in other wounds is well established, and that it may be absolutely necessary after linear fracture of the skull is shown by those cases in which the trephine or the autopsy has disclosed a purulent collection between the dura and the bone. It must be remembered that the fracture has already established a communication between the meninges and the exterior, that this communication is a dangerous one, and that while the trephine increases it, it also removes much of its danger. A free opening into an inflamed or suppurating cavity is as beneficial as a small one is dangerous.

In punctured fractures all admit the value of the trephine, and even those who are most inclined to delay or restrict its use elsewhere do not object to its early application in these cases.

In simple fractures with or without depression the general practice is not to interfere unless or until severe brain symptoms indicative of compression or intra-cranial inflammation appear. The reasons for this are of two kinds: the frequent uncertainty of the diagnosis; and the less chance of intra-cranial inflammation so long as the skin remains unbroken. It happens, too, not infrequently that the depression is gradually overcome by the constantly acting intra-cranial tension, which is estimated by different observers to be equal under normal circumstances to from eight to twenty-five millimetres of mercury and is susceptible of temporary increase. The principal drawback to the expectative method, when successful, is the possibility that a source of irritation may remain which will lead to later intellectual or nervous disturbances, especially to epilepsy; and it is possible that the antiseptic method may prove so efficient in removing the dangers incident to exposure of the cavity of the cranium that surgeons will consider it justifiable in cases of undoubted depression to cut down upon the fracture immediately with a view to prevent the possible occurrence of these late accidents, just as they now consider it proper to do so after these or the earlier inflammatory ones have made their appearance.

A limited paralysis in a case of suspected fracture is a positive indication for the application of the trephine, although its value is much greater when the paralysis is primary than when it is secondary, for the former indicates an existing, permanent lesion of the brain immediately under the seat of fracture, while the latter may be due to meningitis or encephalitis at some distance from the fracture. A beautiful example of operation followed by recovery in a case of this kind was reported by Lucas-Championnière.[1] The patient was brought to the hospital unconscious with a scalp wound above and in front of the ear, and soon showed paralysis of the arm of the other side. The wound was enlarged and carried down to the bone, a fissure found and traced forward about an inch to a distinct fracture, the trephine applied, and a splinter penetrating the dura mater removed. The weight of evidence points

[1] La Trépanation guidée par les Localisations cérébrales, Paris, 1878.

strongly to the fact that these localized paralyses are always due to lesion of the cortex of the brain under the anterior half of the opposite parietal bone, in a region, now known as the motor area, lying on either side of the fissure of Rolando, and corresponding to a line drawn on the scalp from a point in the median line $2\frac{1}{5}$ inches behind the crossing of the coronal sutures, to another one, in front of and above the ear, found by measuring $2\frac{4}{5}$ inches directly backwards from a point on the posterior edge of the external angular process of the frontal bone a little below the upper margin of the orbit, and then $1\frac{1}{5}$ inches directly upwards. This line is called the Rolandic line, and the motor area is in the form of a parallelogram an inch wide traversed centrally by it and stopping half an inch short of the sagittal suture. The upper third of the area is the centre for the lower extremity, the middle third for the upper extremity, the lower third for the face, and the centre for articulate speech is at its lower anterior angle or a little below and in front of it.

Convulsions are an indication for trephining, only when they are localized and persistent, and especially if they alternate with paralysis of the same muscles.

In operating for the removal of depressed bone the necessary opening may be made in the undepressed portion with the trephine or bone pliers, or, if there is a projecting point, with Hey's saw. Whichever instrument is used the utmost care must be taken to avoid injury to the dura mater, and the graphic warning of Sir Astley Cooper, although somewhat overstated perhaps, may be repeated to enforce this injunction. The surgeon should remember, he says, that "there is only the thinness of paper between eternity and his instrument." And for a similar reason I would urge the employment in the dressing of the wound of the antiseptic method in the most rigorous manner possible. The wound should be washed with the carbolic solution, the head shaved and washed with the same, and then completely covered with the gauze. If the wound is in such a position that the gauze cannot overlap it widely enough to insure its protection, the edge of the dressing on the narrow side should be fastened down with bands dipped in collodion or with adhesive plaster, or the gauze may be discarded and the wound kept covered with compresses wet with carbolized oil or even with the watery carbolic solution. An icebag during the first few days has seemed useful. If the edges of the skin wound are not too much bruised they should be brought together with sutures, and an opening left for drainage.

The general treatment consists of perfect rest and quiet, low diet, laxatives, and avoidance of stimulants. If the latter are required immediately after the accident they must be given cautiously, and discontinued as soon as reaction begins.

Fractures of the Base.—Operative interference in these cases is rarely called for. Mr. Hewett mentions a case in which the roof of the orbit was removed through a wound above the eye, and another in which the trephine was applied successfully near the foramen magnum. The general treatment is the same as that of fractures of the vault, and some surgeons use calomel freely to check inflammation.

CHAPTER XIII.

FRACTURES OF THE VERTEBRÆ.

Fractures of the vertebræ have this in common with fractures of the skull that most of their importance depends upon the associated injury of the nerve centres and trunks contained within their canal, but they have in addition the importance due to the function of the spine as a support for the head and trunk. Upon the integrity of this support depend not only the power of locomotion, but also grace of carriage and dexterity in the use of the limbs. The importance of the nerve elements contained within the spinal canal is second only to that of those lying within the cavity of the cranium; their injury may result promptly in death, or in a permanent disability which may be considered even worse, and even their lesser injuries may be followed by consequences in the way of limited paralysis which make life a heavy burden.

The spinal cord, occupying the centre of the vertebral column, is efficiently protected against any external violence that is not sufficient to break the bones that constitute the latter, or the ligaments and muscles that bind those bones together; and the column itself is constituted in a manner that combines elasticity and mobility with the necessary firmness and rigidity. The bodies of the vertebræ, increasing in size from above downwards in correspondence with the variations in the weight and strain which the different ones are called upon to bear, are composed of spongy tissue and separated from each other by the elastic inter-vertebral cartilages, and prevented from changing their positions by the interlocking of the articular processes upon the sides. The general form of the column is that of a tall narrow cone with a double antero-posterior curve which increases its elasticity, and its component parts are strongly bound together by ligaments and muscles allowing a range of motion which, while small between each pair of vertebræ, is in the aggregate considerable. Mechanically, therefore, the spine is exposed to fracture by direct violence, like other bones, and by indirect violence through exaggeration or straightening of its normal curves.

According to the statistics in the tables in Chapter I., fractures of the spine are relatively very rare, only 172 cases being found in the 51,938 fractures treated in the London Hospital during a period of thirty-five years. Gurlt collected, however, upwards of 300 cases in which this diagnosis was certain and constructed from them the following tables, which show the relative frequency with which the different vertebræ are broken and with which they occur at the different ages and in the two sexes:—

Vertebræ.	Fractures.					
	Fatal cases.		Recoveries.		Totals.	
1st cervical	6		0		6	
2d "	11		0		11	
3d "	12		1		13	
4th "	26		2		28	
5th "	39	In 98 cases.	5	In 7 cases.	44	
6th "	44		2		46	
7th "	26		4		30	
Total	164		14		178	
1st dorsal	9	4 cases of fracture of cervical and dorsal vertebræ.	1		10	
2d "	8		1		9	
3d "	10		0		10	
4th "	11		0		11	
5th "	10		2		12	
6th "	11		1		12	
7th "	7		1		8	
8th "	7		1		8	
9th "	8	In 71 cases.	3	In 24 cases.	11	
10th "	11		6		17	
11th "	19		6		25	
12th "	35		8		43	
"lower"	0		8		8	
	146		38		184	
1st lumbar	34	In 17 cases of fracture of lumbar and dorsal vertebræ.	11	In 8 cases of fracture of lumbar and dorsal vertebræ.	45	
2d "	16		7		23	
3d "	3		6		9	
4th "	3		2		5	
5th "	0		0		0	
	56		26		82	
Gross totals	366 vertebræ broken in 217 cases.		78 vertebræ broken in 53 cases.		444 vertebræ broken in 270 cases.	

This table shows that, comparing the different regions, fractures of the cervical and dorsal vertebræ are about equally frequent, 178 and 184 respectively, while those of the lumbar vertebræ, 82, are much less common; that the fatal cases of fracture of the cervical vertebræ are, however, considerably more numerous, actually and relatively, than those of the two other regions; and, comparing the different vertebræ, that the fifth and sixth cervical, the last dorsal and the first lumbar are more frequently broken than any of the others; and that it is common in fractures of the cervical and dorsal regions for more than one vertebra to be broken at the same time.

In the following table the cases are arranged according to location, age, and sex:—

Age.	Cervical.				Dorsal.				Dorsal and lumbar.				Lumbar.				Totals.			
	Fatal.		Recov		Fatal.		Recov		Fatal.		Recov		Fatal.		Recov		Fatal.		Recov	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
15 to 19	4	1	..	..	1	..	2	..	..	1	1	..	4	..	1	..	9	2	4	..
20 " 29	16	3	4	..	15	3	5	1	4	..	1	..	7	..	2	..	42	6	12	1
30 " 39	17	..	1	..	22	..	2	..	4	..	3	..	3	..	4	..	46	..	10	..
40 " 49	21	1	1	..	10	1	6	..	4	1	2	..	4	1	1	..	39	4	10	..
50 " 59	7	..	..	..	5	2	3	..	1	..	..	..	1	..	..	..	14	2	3	..
60 " 69	3	1	..	..	2	1	..	..	1	..	..	..	1	..	2	..	7	2	2	..
70 " 79	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	..	1
80 " 89	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	1	..	..
"Adults"	23	1	1	..	8	..	5	..	1	..	1	..	..	..	3	..	38	1	10	..
Totals	92	9	7	..	63	7	23	1	15	2	8	..	26	1	13	1	196	19	51	2
	108				94				25				41				286			

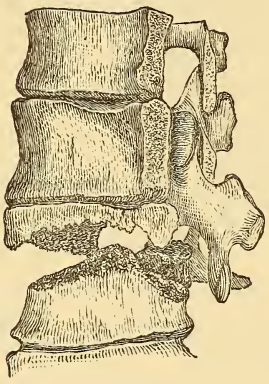
This table shows the extreme rarity of fractures of the spine in childhood and old age, especially in the former, the youngest case being sixteen years old, the oldest eighty-three. Gurlt attributes the rarity in childhood to the absence of bony consolidation of the epiphyses, but I am more disposed to consider it the result of the greater elasticity of the ligaments, which, as is well known, permits a greater freedom of motion in most joints during childhood than during adult life. The great number of cases occurring between the ages of twenty and fifty years, and the comparative infrequency of the injury in women must be attributed to the greater exposure to the accidents which may cause fracture of the spine incident to the occupations of males in the prime of life.

By a detailed analysis of the cases which furnished these tables Gurlt ascertains that the part most frequently fractured is the body of the vertebra, that is, in about two-thirds of all cases, or in more than half of the fractures of the cervical vertebræ, in about seven-eighths of those of the dorsal vertebræ, and in about all of those of the lumbar vertebræ. Or, in general terms, fractures of the bodies of the vertebræ begin at about the middle of the cervical region and increase in frequency downwards. Simultaneous fracture of two or more vertebræ is common in the cervical and upper dorsal regions, less common in the lower dorsal, and rare in the lumbar region. Fracture of one or more of the vertebral processes either of the same or of adjoining vertebræ is common.

Pathology.—The fracture of the body of a vertebra may be complete or incomplete; the line of fracture may extend only partly through it or entirely across it, or it may be broken into several fragments, or compressed, or impacted. The line of fracture, if single, may be vertical, horizontal, or oblique in any direction; the first being found almost exclusively in the cervical and upper dorsal regions, the two latter and multiple fractures occurring everywhere. The transverse and oblique fractures lie, as a rule, nearer the upper than the lower border of the bone, and may pass from the upper to the anterior surface, leaving the posterior and lower surfaces unbroken, and in these cases the upper fragment preserves its relations to the overlying vertebra and is displaced

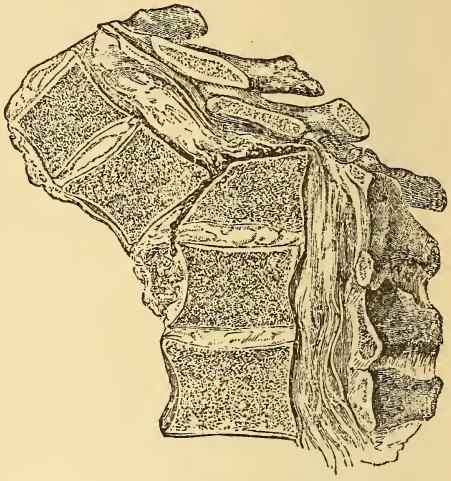
with it forwards and downwards, producing a change in the long axis of the spine characterized by an angle having its apex directed backward at the seat of fracture. This displacement narrows the antero-posterior diameter of the spinal canal and lacerates or compresses the spinal cord

Fig. 134.



Transverse fracture of vertebra.

Fig. 135.

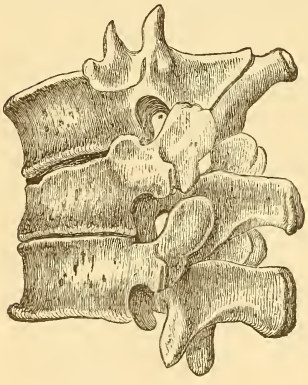


Displacement of the vertebræ causing compression of the spinal cord.

within it. If the line of fracture is oblique, and if fracture or dislocation of the oblique processes is associated with it, the displacement is inclined to the corresponding side either directly or by rotation.

Compression of the body of a vertebra, similar to that observed in other spongy bones, is found either in combination with comminuted fracture or alone, and involving one or several vertebræ. The conditions of its production are not entirely known, but one is thought to be an unusual degree of softness or porosity of the bone allowing it to yield under the pressure exerted by forcible bending forwards of the spinal column. When this movement of forward flexion is carried beyond its normal limits, either the posterior portions of the vertebræ must separate from each other or the anterior portions must approximate by condensation of the inter-vertebral disks or of the bone. When the latter takes place, as in the circumstances under consideration, the concave surfaces of the body of the vertebra are flattened, and its anterior surface made shorter than its posterior one, the compression being of course more marked the greater the distance from the fulcrum (fig.

Fig. 136.



Compression of the last dorsal vertebra.

136). The compression may be so extreme that the intervertebral disks above and below the affected vertebra are brought into contact with each other in front, the substance of the bone being partly compressed and partly forced out upon the sides or behind into the spinal canal (figs. 137 and 138), compressing the cord. With this compression may

Fig. 137.

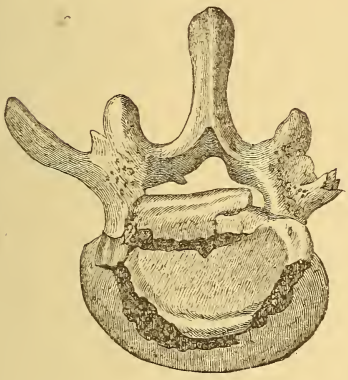
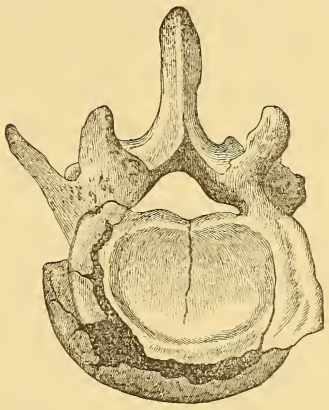


Fig. 138.



Fracture with compression of the 3d and 4th lumbar vertebræ.

be associated fracture or fissure of the body, and especially fracture of the processes of the same or the adjoining vertebra. The same shortening of the anterior portion of the body may be produced by splintering of part of the bone or by impaction of one fragment into another lying above or below it. This latter condition was found in four of Gurlt's cases, three times in the twelfth dorsal and once in the first lumbar vertebra.

Fracture of the vertebral arches, according to Gurlt, is found in about half the cases of fracture of the cervical vertebræ, and only in one-seventh of those of the dorsal, and one-eighth of those of the lumbar. On the other hand, Dr Wyman[1] reported eleven cases of supposed fracture of the arches of the fourth and fifth lumbar vertebræ between the lower articular and the transverse processes, all old and ununited, four of the specimens being taken from ancient Indian graves. The nature of these supposed fractures is in doubt, and it is thought by some that they are merely instances of arrest of development. (See p. 270.)

Gurlt attributes the frequency of this form of fracture in the cervical spine to the comparatively greater breadth and less height of the arch and to the absence of that protection which is furnished in the dorsal and lumbar regions by the larger and stronger spinous, transverse, and oblique processes. In fractures by direct violence, which Gurlt seems to have had principally in mind, this explanation would be sufficient, but Wyman's cases, if they are to be accepted as fractures, indicate an unsuspected frequency in the lumbar region and a different mechanism. Wyman

[1] Boston Med. and Surg. Journal, Aug. 12, 1869.

calls attention to the fact that the articular processes of the lumbar vertebræ are widely separated from each other, as compared with those of the dorsal vertebræ, and are connected only by a narrow neck, and he attributes the fracture to extreme backward flexion or to the shock of a fall upon the feet. It seems not improbable that some of the severe strains of the lower portion of the back which leave a more or less marked permanent weakness or sensitiveness of the part may be fractures of the arch without displacement and possibly without union. When the arch is broken on each side the intermediate portion bearing the spinous process may be driven into the spinal canal and cause fatal laceration or compression of the cord. Gurlt's statistics contain six such cases, affecting the fifth, sixth, and seventh cervical vertebræ.

The spinous processes are broken most frequently at those points where they are longest and thinnest, nearly one-fourth of the cases occurring in the cervical spine, more than half in the dorsal, and about one-eighth in the lumbar; and often several adjoining ones are broken at the same time. In the dorsal region this fracture usually accompanies fracture of the body of one of the vertebræ above or below it. Isolated fracture of a spinous process may occur as the result of direct violence, or, possibly, of muscular action, and the displacement is either directly downwards or to one side. Sir Astley Cooper saw a case in which three or four of the processes were broken off by an effort to support a heavy wheel. The patient, a boy, passed his head between the spokes and took the weight upon his shoulders; it proved too great and he fell, bent double. The muscles were torn upon one side, producing obliquity in the line of the spine at the seat of fracture, the fragments being displaced to the other side. There was no paralysis, and the patient recovered promptly with integrity of functions, but persistence of the deformity. Malgaigne saw a case in which the spinous process of the axis was broken by the passage of a cart across the shoulders and neck. The patient died of associated injuries, and the fracture was verified by a post-mortem examination.

Fracture of the *transverse or oblique processes* occurs in combination with other fractures in about one-sixth of all cases, but is rare except in such combination. In the few instances in which it has occurred alone it was the result of gunshot injury. As a complication of other fractures the proportion of its occurrence for the transverse process is greatest in the cervical and next in the lumbar and dorsal regions; for the oblique processes it is greatest in the cervical and smallest in the lumbar. Fracture of a transverse process of a dorsal vertebra may lead to fracture of the rib which articulates with it, and fracture of the transverse process of a cervical vertebra may seriously injure the vessels contained in the spinal canal. Fracture of an oblique process exposes to dislocation of the vertebra with all its accompanying dangers.

The ligaments which bind the different vertebræ together are torn in fracture to an extent which varies with the severity of the injury and the degree of the displacement, and the intervertebral disks may be torn, displaced, or compressed. In rare cases the injury may be confined to the ligaments and disks, real dislocation without fracture, although the distinction cannot be made during life. I saw at La

Charité, in 1874, in the service of Prof. Trélat, a specimen of such a dislocation between the sixth and seventh cervical vertebræ produced by forced flexion of the neck forwards. The yellow ligament was entirely torn off and the inter-vertebral disk crushed, but no bone or process was broken. The patient died by asphyxia within twenty-four hours after the accident. The muscles and tendons, too, are unusually torn, especially those lying nearest the bones and ligaments; and extravasations of blood form as after other fractures and extend along the cellular interspaces between the muscles and in front of the spine, sometimes into the posterior mediastinum, and sometimes into the retro-peritoneal tissues, surrounding the kidneys and the iliacus and psoas muscles. Ecchymoses may appear on the face or chin after fracture of the cervical vertebræ, and as low even as the loins in other cases. If the displacement is such as to injure the cord large collections of blood may form within the spinal canal, and in some fractures of the cervical vertebræ the vertebral artery is divided.

The spinal cord, the diameter of which is considerably less than that of the canal in which it lies, is suspended within the dura mater, which is itself loosely connected with the bones and separated from direct contact with them in most places by a rich venous plexus. The medullary portion of the cord ends at the first or second lumbar vertebra, and its lower portion is enveloped by the numerous nerve trunks which pass downward to form the cauda equina and the lumbar and sacral plexuses. The cord is injured directly only when the lumen of the canal is considerably encroached upon by the displacement of a fragment or of a vertebra, but it can be compressed by extravasated blood or by inflammatory exudations. Extravasated blood usually lies between the dura and the bone behind or on the sides, and is furnished by the veins just mentioned. The cord itself is seldom the seat of any considerable hemorrhage even when it has been badly crushed or lacerated. Occasionally the cord is penetrated by a sharp fragment, but usually the dura mater is untorn and the cord is crushed between the anterior portion of one fragment or vertebra, usually the lower, and the posterior portion of another, usually the upper. This crushing presents all degrees, from a slight flattening to complete rupture either structural or functional by disorganization of the tissues.

Figure 139 represents the lower portion of the spinal cord after simple transverse fracture of the first lumbar vertebra. The patient died on the nineteenth day. The spinous and left transverse processes encroached upon the cord which was lacerated at the lumbar and dorsal junction. The membranes were entirely torn across, and "the tubular nerve filaments have been curiously dissected out by the pus in which the cord was bathed."

Fig. 139.

Laceration of the cord. (U. S. Med. and Surg. Hist.)

Etiology.—Besides those causes, general and local, mentioned in Chapter IV., which predispose to fractures in general, there are two local ones which lead occasionally to fracture of the spine—aortic aneurism and ankylosis following spondylitis deformans and due to the growth of osteophytes or ossification of the ligaments and intervertebral disks. The first acts by causing absorption of the bone, the loss of substance sometimes involving almost the entire body of the vertebra and opening the spinal canal; this allows the column to bend forward, and brings a strain upon the articular processes which they are not prepared to meet and under which they break. The second, ankylosis, favors fracture, especially when it involves several adjoining vertebræ, by the rigidity which it creates, and the powerful fracturing leverage thus furnished to movements of flexion even within the normal range. In short, it transforms a row of short bones movable upon each other into a rigid long bone.

The *immediate causes* are muscular action and external violence. The former is exceedingly rare; one case has been already mentioned in Chapter IV., in which the neck was broken by the forcible bending of the head backward in an effort to save it from striking against the ground when the patient was diving and found the water less deep than he had supposed. It is doubted by some if such are really cases of fracture by muscular action, and it is thought that although the face was not bruised, and the patient declared it had not struck the ground, yet it might have done so. Schede,[1] however, reported at the Tenth Congress of the German Gesellschaft für Chirurgie a case which seems unquestionable, for the patient's hands struck the ground and protected the head. The patient survived three weeks. Schede says three analogous cases have occurred; in each the fracture was of the fourth or fifth cervical vertebra. An undoubted case of fracture by muscular action is quoted by Gurlt from Lasalle; the patient was a lunatic who, in his efforts to free himself from a chair, in which he had been bound, bent his head forcibly backwards and forwards and produced a dislocation between the fifth and sixth cervical vertebræ with fracture of several processes. In other cases in which the patients have tried to lift a heavy weight by placing the shoulders under it and then, finding themselves unable to support it, have fallen, it is not always easy to distinguish between the effects of the muscular effort and those of the falling weight.

Of 286 cases tabulated by Gurlt according to the character of the fracturing force, 176 were caused by a fall from a height, and 50 by the fall of a heavy body upon the patient. The cases in which the action is exerted directly upon the bone that is broken are relatively few in number, and the great majority are fractures by *indirect action*. To understand the mode of production of these latter it must be remembered that the spinal column is like a many-jointed rod possessing a flexibility which varies at different points. This flexibility, which is largely due to the elasticity of the inter-vertebral disks, is restricted by the interlocking processes and ligaments, and its variations in extent and direc-

[1] Supplement to Ctblatt für Chirurgie, 1881, No. 20, p. 33.

tion are due to the differences in the form and relations of the articular processes. The range of motion is greatest in all directions in the cervical portion and is least in the dorsal portion, especially in the antero-posterior direction, while the lumbar portion allows free flexion but almost no rotation. This combination of different degrees of flexibility seems to account for the greater frequency of fracture at certain points, according to a mechanism pointed out by Sir Charles Bell who compared the spine to a jointed fishing-rod which breaks, when over-bent, close to a rigid joint rather than in the centre of one of its long elastic pieces. In like manner the spine breaks most frequently at or near the points where a flexible portion adjoins a comparatively rigid one, for example at the union of the cervical and dorsal and of the dorsal and lumbar portions. These points correspond to the ends of the normal curves of the spine rather than to their centres.

Indirect fracture takes place usually by forced flexion beyond the normal limits, whether the force is exerted by a fall upon either end, by the action of a heavy body, or by flexion of the trunk; and it has been shown by Philipeaux's experiments upon the cadaver that the forced bending forwards of the trunk causes most commonly an oblique fracture of the body of the eleventh or twelfth dorsal vertebra, the line of fracture running forwards and downwards. In only a few of the cases collected by Gurlt was the fracture caused by the simple flexion of the trunk; in most the mechanism was more complicated, by the fall either of the body from a height or of a weight upon it, or by an unavailing effort to lift or resist a weight, the fracture taking place in the latter case at some distance from the point where the weight rested or struck; and in one unique case the atlas was broken in rough play, the patient being seized by the brim of his hat, and his head forcibly bent from one side to the other while he was forced down upon a seat.

The fractures by direct violence are few, only fourteen in Gurlt's collection; and the force was exerted in almost every case upon the posterior portion of the column, fracturing first the spinous processes or the arches, and then in some cases the bodies of the vertebræ, or causing a dislocation. In most of these cases the violence was a blow, and in only one was the fracture compound, a fracture of the neck caused by two cows walking over the patient as he lay in a ditch.

Symptoms and Diagnosis.—The symptoms of fracture of the spine vary with the position and the portion of the vertebra involved, and therefore need a separate and detailed consideration in connection with the different groups of fractures. But there are certain general symptoms common to most which may first be mentioned. After the first shock of the injury, which usually passes off without permanent impairment of the intelligence, the patient complains of a localized pain at the seat of fracture increased by manipulation or movements. There is usually a recognizable deformity consisting of a change in the direction of the spine, a more or less marked angular projection backwards with or without swelling of the surrounding soft parts; crepitation can sometimes be made out by the surgeon, but more commonly it is appreciable, if at all, by the patient himself when his body is moved. The most

important and constant symptom is paralysis, motor and sensory, more or less complete, of the limbs and the portion of the body lying below the fracture. If complete its upper limit is usually sharply defined by a line crossing the trunk and corresponding to the adjoining limits of the regions supplied by the nerves that leave the column immediately above and below the point at which the cord has been injured. The consequences of this paralysis, if it involves the abdominal muscles, bladder, and rectum, are retention of urine and feces, followed by incontinence of one or both, by alkaline fermentation of the former, and cystitis. Respiratory difficulties, sometimes severe enough to cause death, appear when the fracture involves the upper portion of the spine, the result of the paralysis either of the abdominal muscles or of the diaphragm. There is also great tendency to sloughing at all points of pressure within the paralyzed region, especially over the sacrum, trochanters, the tuberosities of the ischii, and along the back. The sloughs appear promptly, sometimes within two or three days, are usually symmetrical, and often hasten death even if they are not its immediate cause.

The paralysis is usually so complete that even reflex contractions cannot be excited, and the muscles quickly lose their contractility under electrical stimulus. If the paralysis of sensation is incomplete, so that pinching can be only slightly felt, the ability to distinguish between heat and cold may exist unaltered; and occasionally there is hyperæsthesia of the surface so marked that the slightest touch causes pain, and in a few cases sharp shooting pains have been observed in the course of the main nerve trunks of the legs, excited by slight movements of the trunk or of the limbs, but not by direct pressure upon the spine. This extreme sensibility has been attributed to the irritation of splinters pressing upon the spinal cord, but the opinion lacks anatomical proof. It is also a common symptom of commencing improvement, appearing with the return of reflex irritability and muscular twitchings or spasms.

Tonic or clonic muscular spasms are observed in the anus, and more rarely in the legs and body, and may be excited by a great variety of causes, such as irritation of the surface by a touch or a current of cold air, or change of position of the limbs or of the body.

The temperature of the paralyzed portions shows changes which are not always the same, being sometimes increased, sometimes diminished, and sometimes unaltered. Marked elevation of the temperature has been observed in experiments upon animals after complete or partial division of the spinal cord in its upper portion, and the same has been noticed clinically. Gurlt quotes a case from Sir Benjamin Brodie, in which, after fracture of the fifth and sixth cervical vertebræ with slow diaphragmatic respiration, small pulse, and livid countenance, the temperature between the scrotum and thigh rose to 111° Fahr.; the patient died in twenty-two hours. I saw in Prof. Gosselin's wards at La Charité in 1875 an example of the same injury, fracture of the fifth and sixth cervical vertebræ caused by a fall while turning a somersault, with forced flexion of the head upon the chest, in which death by asphyxia followed in twenty-four hours, the temperature rising to 106°. A symptom in this case and in the similar one of Trélat's above mentioned was the expectoration towards the end of life of a

good deal of blood, and at the autopsies the lungs were found very much congested. In Gosselin's case the spinal cord was compressed by the displaced vertebra and congested, but not divided. A very remarkable case of high temperature following injury of the spine was reported by Mr. Teale.[1] The elevation was constant for several months, the maximum being 122° Fahr. The patient recovered.

Persistent and obstinate vomiting has been observed in some cases, most frequently after fracture in the lower cervical portion, and at the autopsy of one such case the mucous membrane of the stomach showed numerous ecchymoses, and there was half-digested blood in the cavity of the viscus. In two cases this vomiting, which was accompanied by complete constipation, became fecal, and remained so until a movement of the bowels was obtained. In both cases the fracture was of the cervical spine, and the paralysis was complete in the lower limbs and almost complete in the arms.

Priapism, more or less complete, was observed, according to Gurlt, in 31 of 96 cases of fracture of the cervical and two upper dorsal vertebræ, 16 times in 133 cases of fracture between the third dorsal and second lumbar vertebræ, and never in fracture below the latter. It appears promptly, usually on the first or second day, and seldom lasts longer than a fortnight. Notwithstanding the insensitiveness of the penis it may be caused or increased by the use of the catheter. On the other hand, in one case the erect organ became relaxed as soon as the catheter had passed over half the length of the urethra. Ejaculations are very exceptional, there being only four instances in Gurlt's collection, all of them in cases of fracture of the cervical spine; in one case they were continuous, in another they were excited by the introduction of a catheter.

Fracture of Atlas and Axis.—The intimate relations existing between these two bones and the medulla oblongata, and their position above the root of the phrenic nerve as well as above those of the other nerves supplying other muscles which aid in respiration, make their injury especially dangerous, and have probably led to the generally received opinion that their fracture is, as a rule, immediately fatal. Gurlt's cases show, however, that this opinion is not correct, for in the eleven in which the nature of the injury was demonstrated by the autopsy, death occurred immediately in only two, and in only two others within an hour after the injury was received. In the other cases the patients survived for a considerable length of time, thirteen days in one, although some of them at the last died suddenly, apparently by displacement of the vertebræ due to incautious movements. The fractures were all caused by external violence, sometimes slight, as a fall from the bed while trying to reach down to the floor.

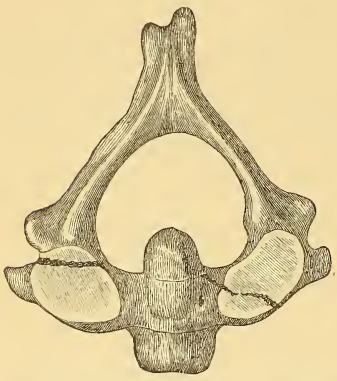
The parts broken in ten of these eleven cases were: the odontoid process alone once; the odontoid process and posterior arch of the atlas three times; the posterior arches of the atlas and axis three times; the posterior arch of the axis alone once; the spinous process of the axis twice. In six of the cases there was associated fracture of the cervical or dorsal vertebræ, and in no case was the transverse ligament torn. Figure 140, taken from a specimen in the museum at Braunschweig, shows a fracture

[1] Lancet, March 6, 1875.

of the superior articular surface of the axis. The patient was twenty-four years old, and died in a few hours after falling out of a wagon upon his head.

Dr. Chas. T. Hunter[1] explains the frequency of fracture of the axis, as compared with that of the atlas, or with rupture of the transverse ligament, by the fact that the structure of the body of the axis is comparatively spongy, and he shows that its weakest point is about one centimetre below the neck of the process.

Fig. 140.



Fracture through the superior articular surfaces of the axis. (Gurlt.)

The symptoms of this fracture are so variable and so indefinite and have so much in common with simple dislocation of one bone upon the other, or of the atlas upon the skull, that the diagnosis is extremely difficult. On the one hand, the patient may die instantly; on the other, he may survive a longer or shorter time, either completely paralyzed or presenting no important symptoms, and then die suddenly by displacement of the fragments or gradually by extension of the symptoms, or in consequence of other injuries, or, if the diagnosis in some such cases may be accepted, may even get well. The symptoms of local pain and stiffness of the neck are too indefinite to be of any service, and paralytic symptoms may be entirely absent, as in Gurlt's second case where the patient walked for two hours after the accident to reach home and developed no paralysis until the following day. Death took place suddenly on the eighth day, and the autopsy showed fracture of both arches of the atlas and of the odontoid process.

The symptoms in those of Gurlt's eleven cases which survived long enough to present any, or in which any are recorded, were complete paralysis of all the parts below the fracture in some, partial paralysis in others, only a slight diminution of sensibility in the left arm in one, pain in the neck or occiput in six, rigidity of the neck in most, absence of recognizable deformity in all, distinct crepitation in one, and falling forward of the head upon the breast in one. All of these symptoms—pain, rigidity, paralysis, sudden death—may be the result of dislocation as well as of fracture; and as dislocation has in addition no characteristic, general or local, symptoms which serve to distinguish it the differential diagnosis must usually remain in doubt.

Fractures of the lower five Cervical and first two Dorsal Vertebræ.—The special characteristics of fractures of this region are due to the inclusion within it of the roots of the phrenic nerve and brachial plexus. The former passes out through the intervertebral foramen between the third and fourth cervical vertebræ, either coming from the fourth cervical pair alone, or receiving branches also from the third and fifth pairs. The brachial plexus is formed by the four lower cervical and

[1] Holmes's System of Surgery, Am. ed., vol. i. p. 808.

the first dorsal pairs. Consequently, if the fracture is accompanied by displacement of the fragments and injury to the spinal cord, paralysis of the upper limbs also is caused, and if the fracture is high enough in the region to involve the phrenic nerve directly or by extension death follows promptly, preceded by the respiratory symptoms peculiar to lesion of this nerve. As the tables quoted from Gurlt show, fractures are more common in this region than in any other, and this frequency is due especially to the numerous fractures of the fifth and sixth vertebræ, which in each case are far in excess of those of any other vertebra except the last dorsal and the first lumbar.

Here too, as after fracture of the atlas and axis, are found cases in which the patients present only symptoms of paralysis for a longer or shorter time, and then die suddenly of asphyxia in consequence of some accidental or intentional movement of the head, which probably causes compression of the phrenic nerves by displacement of the fragments. Gurlt's tables contain 7 of these sudden deaths; in 4 of them the immediate cause was not known or is not indicated; of the remaining 3 death was caused in one by the barber who turned the patient's head to one side while shaving him, in another by the patient's wife who passed her hand under his neck and tried to raise him, and in the third by the patient's daughter, by putting her arms about him to embrace him. Death was accompanied in most of the cases by slight convulsions, and took place at periods varying from twelve hours to twenty-three days after the receipt of the injury.

The paralysis in fractures of the portion of this region below the fourth cervical vertebra shows many variations. From the relations of this part to the brachial plexus it might be expected that paralysis of the upper limbs would be a constant symptom, excluding those cases in which there is no displacement, but Gurlt's tables show this paralysis to have been present in less than one-fourth of the cases, that in the majority complete paralysis of the lower portion of the body extended upward at first only to the middle of the breast, the second rib, rarely to the neck, clavicle, or shoulders, and sometimes not even to the umbilicus, although it often advanced to a higher point later in the progress of the case. Paralytic symptoms appeared in the arms, as a rule, either later on the day of the accident or on the following day. The paralysis may be complete in one arm and partial or absent in the other; it may be complete of motion and incomplete of sensation, or the reverse; it may be limited to the arm or to the forearm; or the injury to the nerves may be evidenced by abnormal sensations, such as numbness or prickling in the limb. Hyperæsthesia affecting the whole or part of the limb is occasionally observed, and is sometimes associated with sharp, lancinating, continuous, or intermittent pain, which may be spontaneous or may be excited or increased by the slightest touch of the surface. Tonic or clonic spasms are seen somewhat more frequently than hyperæsthesia, sometimes limited to the arms alone, sometimes involving other muscles also.

An important consequence of the paralysis is the change in the respiratory act due to the withdrawal of the aid of the accessory muscles when the phrenic nerve is uninjured. As a consequence of the paraly-

sis of the intercostal and abdominal muscles, inspiration is effected by the diaphragm alone, and expiration by the weight of the abdominal walls and viscera which sink back to the positions from which they have been displaced by the contraction of the diaphragm. As the expiration is thus purely passive the patient cannot sneeze or cough strongly, and as he is thus prevented from cleaning his lungs of the mucus which collects in them it gives rise to plentiful moist râles. If the phrenic nerve shares in the injury the diaphragm acts very slowly, perhaps not oftener than twice or thrice in the minute, the breathing is noisy or sighing, and the shoulders may be slightly raised at each inspiration. Sometimes a change in the position increases or diminishes the difficulty by modifying the pressure upon the cord. A noticeable slowing of the pulse accompanies this defective respiration. The voice becomes weak, and speech slow and difficult because of the insufficient volume of air; there is a peculiar coloring of the face due to defective decarbonization of the blood, to which Bransby Cooper first called attention, and finally towards the end of life delirium or coma supervenes.

The local symptoms are usually few and obscure, often nothing more than the pain that is felt at the seat of fracture and is increased by pressure or motion. In several cases, according to Gurlt, it was impossible to detect even after death any deformity or crepitation. In other cases there are positive objective signs: an abnormal projection or depression of one or more spinous processes, an irregularity on the posterior wall of the pharynx produced by the displaced body of a vertebra, lateral displacement of one or more spinous processes, and possibly crepitation or abnormal mobility.

The position and mobility of the head vary greatly in different cases. In some cases they show nothing abnormal, in others the head can be moved freely to either side, but not forward or backward, and in others it is held firmly fixed in some one position and any attempt to change that position causes pain. This rigidity is due not to change in the relations of the articular surfaces, but to the involuntary spasmodic contraction of the muscles which is nature's method of preventing the infliction of pain by movement of the parts.

It is apparent that the diagnosis of fracture of this region may be difficult or impossible. The most that can be done in many cases is to recognize approximately the seat of the injury. Thus, paralysis or symptoms of irritation in the arms, even if they first appear after some delay, indicate a lesion above the second dorsal vertebra, although in a few exceptional cases this symptom has existed when the injury was lower on the spine, and was then due probably to an associated brain lesion or a large collection of blood within the spinal canal. If all local and functional signs are absent the diagnosis is of course impossible, and the real nature of the injury may be entirely overlooked until the progress of the inflammation or a chance displacement of the fragments brings it to light.

A remarkable instance of this form was reported by Mr. Simon[1] under the title of *latent fracture of the spine*. A girl fell down an embank-

[1] Surgical Observations, p. 145; quoted in Holmes's Syst. of Surgery, Am. ed., vol. i. p. 795.

ment and injured her neck. She afterwards walked three miles and continued at her occupation in a factory for eleven days. On the fifteenth day she was admitted to St. Thomas's Hospital with vague complaints of pain and tenderness in the neck, but without deformity or paralysis of motion or sensation. Early on the following day she complained of numbness and twitching in the limbs, especially the lower ones, and by the evening voluntary motion was entirely lost in the legs and almost so in the arms, and sensation was impaired in both. There was also high fever with delirium and tympanites. She died on the third day after admission, the eighteenth after the fall.

The autopsy showed a horizontal fracture of the body of the seventh cervical vertebra, gaping a little in front, but with no displacement. The vertebral canal contained, outside the dura mater, throughout its entire length from two inches below the foramen magnum, a large quantity of pus which had spread somewhat along the tracks of the nerves at the inter-vertebral foramina, and had actually emerged through the foramen between the first and second dorsal vertebræ. There was no softening or change recognizable by the microscope in the spinal cord.

A similar case is reported by Erichsen.[1] A woman was admitted into University College Hospital suffering from the effects of a fall upon the back, the symptoms attending which were obscure. There were no head symptoms, no head injury, and no paralysis; but she complained of pain in the neck, and kept the head fixed immovably. A few days after admission, whilst sitting up in bed, she was startled by a noise, turned her head suddenly to learn the cause, and fell back dead.

At the autopsy it was found that the spinous process of the fifth cervical vertebra had been broken off at its root. By the sudden movement it was forced into the space between that and the adjoining vertebra, compressed the cord, and caused death.

In two of Gurlt's cases, fractures of the fifth and sixth cervical vertebræ, the vertebral artery on one side was torn, with free escape of blood between the muscles and into the vertebral canal.

The prognosis is extremely unfavorable. Gurlt's tables contain 96 fatal cases, and only 8 which ended in recovery, and in one of these the symptoms reappeared after a fall and the patient died in consequence. In one-third of the cases death took place within the first four days; in 20 between the fifth and twelfth days: in 11 between the thirteenth and thirty-sixth; and in one case the patient survived five months.

Fractures of the lower ten Dorsal and first two Lumbar Vertebræ.—This region includes another point at which fractures are very common, the lower dorsal and the first lumbar vertebræ. Its position below the original of the brachial plexus prevents the involvement of the arms in the paralysis except in rare cases where this unusual extension is due apparently to the spread of inflammatory softening of the cord or to the pressure of extravasated blood. Paralysis of the lower limbs, the bladder, and rectum, which is one of the common results of fracture in this division as well as in the higher ones, may be entirely absent at the beginning, especially after fracture of the second lumbar vertebra, or,

[1] Concussion of the Spine, p. 50.

more frequently, may be incomplete, the motor paralysis being as a rule more marked than the paralysis of sensation. The latter may extend as high as the lower part of the heart, or may stop at the groin, and sometimes even does not reach above the lower part of the thigh. A common result of the paralysis is the immediate retention of urine and feces, followed, as before mentioned, by incontinence and by alkaline decomposition of the urine and cystitis. This incontinence persists until death takes place or improvement begins. The disturbance in the function of the bowels aided by the flaccidity of the abdominal muscles produces tympanites which makes its appearance usually within a day or two and may be sufficiently marked to interfere with respiration by crowding the diaphragm upwards and opposing its contraction.

In other cases, even of apparently severe injury to the body of a vertebra, there may be an entire absence of paralytic symptoms and even of those of meningeal irritation. Erichsen[1] narrates the case of a young man who was caught in a turn-table which doubled his body forwards and caused intense pain in the back. After remaining a few weeks in hospital he was discharged. His symptoms were inability to stand upright or to walk for more than half an hour, because of the pain it caused in the back and under the ribs. The spinous processes of the tenth and twelfth dorsal vertebræ projected, and there was a distinct depression between them. The spinous process of the eleventh dorsal was broken off and twisted so as to lie directly across to the left side. When lying on his back the patient was unable to rise without the aid of his hands. The legs were wasted, their sensibility and reflex irritability normal. No tinglings, no paralysis of the sphincters, no sensation of a cord about the body. Muscular reaction to the interrupted current equal in all muscles.

Another case, in which symptoms were almost entirely absent, was reported by Dr. Basling in the *Lancet*, Feb. 4, 1882, page 186. The patient, a middle-aged man, had his back forcibly bent while driving under an archway. The only symptoms were slight pain in the back and increase of the interval between the ninth and tenth dorsal spinous processes. He died on the nineteenth day of injuries inflicted at the same time upon the thorax. "The pedicle on both sides of the tenth dorsal vertebra was broken close to the body, and the spine was tilted a little downwards; the fracture also extended transversely through the middle of the body of the vertebra without causing displacement, and without rupturing the anterior or posterior common ligaments. On the external surface of the dura mater, opposite the seat of fracture, there was a deposit of lymph the size of a shilling. The other membranes and the spinal cord itself were quite healthy."

The diagnosis is aided by objective symptoms, which are more marked and distinctive than those found after fractures of the upper portion of the column, because as the fracture in the great majority of the cases involves the body of the vertebra, and is comminuted or accompanied by displacement, there is usually a recognizable deformity consisting in an angular change in the long axis of the spine, with projection of the spin-

[1] Concussion of the Spine, p. 123.

ous process of the broken vertebra or of the one immediately above it. This change in the position of the spinous process is sometimes so marked that the finger can be pressed deeply in between it and the next lower one.

The prognosis, as regards both life and recovery of function, is more favorable than after fracture at a higher point. Gurlt's statistics contain 145 cases, of which 39 recovered more or less completely; in 18 additional ones the patients survived more than three months, with a fair prospect of recovery, but died in consequence of some complication that had no necessary connection with the fracture. In 23 of the fatal cases other severe injuries or complications were present, and apparently caused death. Of the 83 fatal cases which remain after excluding these 23, 1 died in the first twenty-four hours, 33 in the first month, 23 in the second, 8 in the third, and 2 in the fourth; in 16 the patients survived for periods varying between four and fifteen months.

Fractures of the lower three Lumbar Vertebræ.—Fractures of this portion of the spine are, according to Gurlt's statistics, exceedingly rare.[1] The absence of paralytic symptoms and recognizable displacement would make the diagnosis during life practically impossible.

As this portion of the spinal canal contains only nerve trunks, which are better fitted by their texture and comparative independence of each other to resist or escape damaging pressure by displaced fragments than the spinal cord itself is, paralysis may be absent even when the displacement is marked; in some cases it has been complete, both of motion and sensation, over the limbs and abdomen. Mr. Shaw[2] observed four cases of fracture in this region in which there was total absence of paralysis; in the first the displacement was so great that the spinous and transverse processes projected visibly, the spine could not be straightened, and the patient's body remained permanently much bent, yet motion and sensation were retained from the first. In another there was relatively greater prominence of the displaced vertebræ fourteen years afterwards than at the time of the accident, when the patient was eight years old, "but the column was, on the whole, nearly straight, and his muscles were powerfully developed." In another case Mr. Shaw "found the trunks composing the cauda equina lifted one-third of an inch on a bridge of bone formed by the displacement of a fractured lumbar vertebra; but they were in no degree compressed, and showed scarcely any trace of injury."

The patient may, however, be unable to walk in consequence of the loss of support occasioned by the fracture, or he may walk only feebly and in a bent posture. But if union takes place, even if the deformity persists, he may be as strong and capable as before. In short, the prognosis is favorable as regards both life and function.

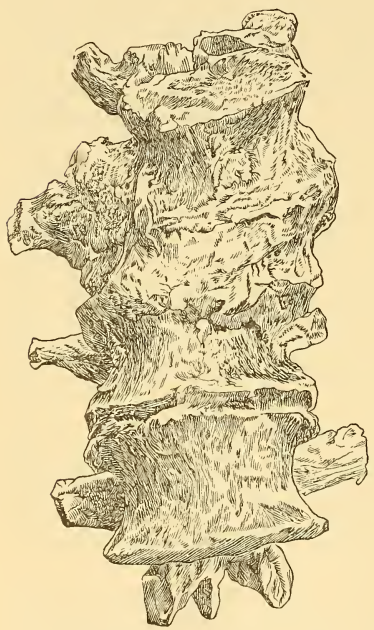
[1] If the specimens of supposed ununited fracture of the arch of these bones, which have been found upon the dissecting-table, in museums, and in old Indian graves, are accepted as such, they raise the question whether similar fractures are not more common than has been supposed, and whether they may not be present, without displacement, in some of the severe, so-called strains of this region. I incline to the belief, however, that they are specimens of arrest of development.

[2] Holmes's System of Surgery, Am. ed., vol. i. p. 804.

Course and Terminations.—The course and terminations of fracture of the spine, with their many variations as regards both the life and principal functions of the patient, have been indicated in the preceding paragraph; we have now to consider the changes effected in the broken bone by the process of repair, and to describe some of the later symptoms with more detail.

Repair takes place as after fracture of other spongy bones, that is, by a callus which may remain fibrous or become bony, and may be larger or smaller according to circumstances. As the displacement cannot be reduced the fragments must unite, if at all, in the positions in which they are left by the accident, and although the normal relations may be thus notably altered and the union remain fibrous the solidity is quite sufficient. The spinous processes frequently unite only by fibrous tissue and remain movable; and sometimes they show a real pseudarthrosis, with capsular ligament and smooth surfaces, although it is questioned by some if this condition has originated in a fracture. In fractures that have been healed for a long time is found the same absorption of projecting angles and surfaces which has been noticed in connection with other fractures, and this absorption is especially marked in the bodies of the vertebræ. If several adjoining vertebræ are broken at the same time the intervertebral disks disappear in part by absorption, and the remaining portions undergo partial or complete ossification, uniting structurally with the vertebræ, and thus forming a more or less extensive, rigid, bony mass (fig. 141). The length of time required for consolidation appears to be greater than for that of other spongy bones, probably because the immobility of the parts is not so complete.

Fig. 141.



Ankylosis by fusion of the vertebræ after fracture.

A number of instances of complete pseudarthrosis have been recorded, and their origin differently interpreted. Gurlt has collected 21 such cases: 1 of the odontoid process, 4 of the spinous processes of the cervical, dorsal, and lumbar vertebræ, and of the sacrum, 3 of the transverse processes of lumbar vertebræ, 11 of the arches of lumbar vertebræ, and 2 of the side of the upper false vertebra of the sacrum. Meckel considered the 11 cases involving the arches of lumbar vertebræ as instances of arrest of development, comparing them to the vertebræ of some reptiles, which consist normally of a separate body and arch, and in which many of the processes also remain ununited. Otto opposed this view, because the position of the false joint does not correspond to

that of the line between the diaphysis and epiphysis, and Wyman,[1] who reported 11 additional cases, and did not know of these earlier ones, held the same opinion for the same reason. Gurlt accepts Meekel's opinion concerning the arches of the lumbar vertebræ, and claims that it is probably true also of the other cases. His reasons are that there is no trace of injury to other parts, and that it is known that fracture limited to a vertebral arch, a spinous or transverse process, is exceedingly rare; that most of the cases relate to the lowest lumbar vertebræ, fractures of which, of any kind, are rare, and in the case of the fifth unknown; and that the identity of the position of the joint in all corresponding cases, and its perfect structure, point strongly to an arrest of development, and are incompatible with a fracture by external violence. Wyman says of his specimens that "the opposing surfaces of bone have the usual roughness, and in some instances the neighboring parts are the seat of irregular bony deposits. In two the surfaces have been worn smooth by mutual friction." Sir Charles Bell[2] mentions and describes another, apparently lumbar, vertebra, which he thought "must have suffered violence of the nature of a diastasis in childhood." "The spinous process is separated [on each side] from the transverse process, so as to divide the ring which forms the canal of the spine. The surfaces are rounded and smooth, showing that they were united by ligament and permitted a certain motion."

Suppuration at the seat of fracture, which is very rare in other bones, seems to be more common after simple fracture of the spine, and is attributed by Gurlt to the greater complexity of the anatomical conditions and to the less perfect immobility maintained during the progress of the case. His statistics contain eight cases in which, excluding instances of suppurative meningitis, more or less pus was found after death at the seat of fracture; in four of the cases the abscess was large, and its walls formed in part by the unbroken ligaments, in one of them the wall of the abscess had ossified. Usually the intervertebral disks are partly destroyed, the articular surfaces eroded, and sometimes the bone carious. In most cases the suppuration was limited to the fracture, but in one the pus had made its way out by several channels through to the muscles and tendons, and had collected in the back.

Inflammation of the end or its envelopes as a consequence of injury to the spine is comparatively infrequent; when it occurs it may be confined to the outer side of the dura mater, creating adhesions between it and the bone, or ending in suppuration, or it may occupy the inside of this sheath, and then be the result either of injury to the cord or, more rarely, of a spinal meningitis without injury to the cord or any paralytic symptoms. In the latter case, the first symptoms are those of irritation in the form of spasmodic twitchings in the limbs, and are followed by paralysis due to compression of the cord by the increasing exudation. With this may come delirium, repeated chills, and sweating. Abscesses within the substance of the cord are extremely rare; only one instance is contained in Gurlt's statistics. As to the recovery of the cord after

[1] Boston Med. and Surg. Journal, Aug. 14, 1869.
[2] Injuries of the Spine, pp. 28 and 83, and plate iii., figs. 5 and 6.

injury, with restoration of function, nothing definite is known beyond the fact that a number of autopsies made at various periods after injury have shown the cord more or less completely divided, or reduced to pulp at the compressed part, or replaced by fibrous tissue. There is nothing to prove that a disintegrated portion can be restored, or that divided cords can be reunited, and it is not easy to see how proof of such a fact could be furnished except by experiment. In those cases in which paralysis has disappeared after a time, it is impossible to know exactly what was the nature of the lesion of the cord that caused it.

The troubles created by paralysis of the bladder are very serious, and often hasten a fatal termination. They begin, usually promptly, with retention, which if not looked for by the surgeon may pass unnoticed, since it gives the patient no pain, until the distension of the bladder has become so great that the urine begins to dribble away through the urethra. This distension is of itself sufficient to cause cystitis. If the retention is noticed, and the catheter used regularly the appearance of the cystitis will be delayed; the urine gradually becomes turbid, ammoniacal, and charged with mucus, and remains so until death or until improvement has taken place in the paralysis. After a period that is usually short, the retention passes into incontinence, either complete or by overflow. The symptoms and usual consequences of the cystitis are such as are commonly observed when the same affection is excited by other causes, and do not require a detailed description here; but in addition to these common ones there are occasionally observed others of great gravity, such as sloughing of the wall of the bladder, and pericystitis with formation of abscesses. In one of Gurlt's cases, there was found at the autopsy a sac filling the pelvis and reaching half way to the umbilicus, and containing nearly a pint of offensive pus and urine; its wall was dark colored, and from it hung numerous soft putrid shreds, the only remains of the bladder. The prostate projected half an inch into this cavity, and the urethra was pervious. A fistulous opening above Poupart's ligament led into the cavity. The ureters and pelves of the kidneys were enlarged and contained purulent urine.

In exceptional cases the bladder wall may be found hypertrophied and its cavity contracted. In two such cases, the patients were 34 and 36 years old, and survived 52 and 33 days. The thickening of the wall was doubtless inflammatory and not a true muscular hypertrophy.

In a few cases a very notable diminution in the quantity of urine has been observed, not more than three or four ounces being secreted in the twenty-four hours. The ammoniacal condition of the urine is due to fermentative changes carried on within the bladder, and not to a modification of the urine itself as secreted. In a few cases it has remained unchanged in the bladder, and in others it has changed spontaneously from clear and acid to turbid and alkaline and back again several times.

Every effort should be made to delay the appearance of this complication and to diminish its severity, and with this object the water must be regularly drawn as soon as the first signs of retention appear. It is usually sufficient to use the catheter twice a day; it must be passed with even more than the usual precautions and gentleness because the patient's insensitiveness creates an additional risk of doing damage un-

wittingly to the urethral wall. After cystitis has appeared and the urine has become turbid, the bladder should be washed once or twice a day, preferably by the aid of a fountain syringe, with warm water either pure or containing carbolic acid, borax, or quinine, or, if decidedly ammoniacal, a little dilute nitric acid.

Bed-sores appear promptly after any fracture that has caused paraplegia, sometimes as early as the second day. The skin at first becomes white, then mottled, and then separates as after blistering; then the deeper part sloughs, and the slough spreads peripherally and in depth. The commonest seat is the skin covering the convexity of the sacrum, then other prominent points upon the back and legs. Not infrequently when the slough over the sacrum separates the bone underneath is found necrosed, and in one instance the fall of this sequestrum opened the vertebral canal, with a fatal result. The cause of this early sloughing has been thought to lie in injury to nerves or nerve centres presiding over the nutrition of the parts; but Mr. Shaw[1] explains it by the pressure which is continued for a length of time and with an absence of interruption unknown except in connection with paralysis. Not only is the patient unable to move, but he is insensitive to the prolonged pressure, and does not seek to change his position or to have it changed. He lies absolutely motionless in one settled position; the pressure interrupts the circulation at certain points, and, if this interruption continues unrelieved, the part dies. The presence of urine or liquid feces may prove an additional source of irritation, as may also creases or irregularities in the bed-clothing, and lack of attention and scrupulous cleanliness. The rapid improvement which sometimes takes place in these sloughs, even when the paralysis remains complete, as soon as the consolidation of the fracture is sufficiently advanced to allow the patient to be readily moved, is an additional demonstration that they are due to the pressure and not to the paralysis. Some cases which have recovered with permanent paraplegia have shown, on the other hand, a very marked tendency to the formation of sloughs on slight provocation.

Bed-sores are a serious complication, for the suppuration is exhausting, increases the difficulty of nursing the patient properly, and involves the risk of pyæmia. Their formation may sometimes be averted, or least delayed, by painting the exposed parts with flexible collodion; but the best means of preventing them, or of healing them when formed, is the use of water beds or cushions which equalize and distribute the pressure. Pressure may be taken temporarily off parts which threaten to slough by the use of inflated rubber-rings or of several thicknesses of plaster placed on each side of the affected part. Great care must be taken to keep the sheet on which the patient lies smooth and dry, and to protect the perineum and buttocks from being soiled by dribbling urine and feces.

In those cases in which the patients survive the injury and its more immediate consequences, it is sometimes found that the paralysis gradually diminishes and may even disappear entirely. The beginning of the improvement is marked by the appearance of sharp darting pains in

[1] Holmes's Syst. of Surg., Am. ed., vol. i. p. 810.

the limbs and of muscular twitchings excited by slight causes, such as pinching or touching the skin; then the power of voluntary motion returns, first in one muscle, then in another, usually manifested first by movements of the toes, for the great majority of the cases of improvement and even of survival are those in which only the lower limbs are paralyzed. Sensation returns usually before motion; the bladder is found to be again able to retain a certain quantity of urine and to expel it with some force; and a similar improvement is presented by the rectum, although, as a rule, even in the best cases, the functions of the rectum and bladder remain partially and permanently disabled. There is usually partial incontinence of both urine and feces. The improvement in the paralysis may be very slight, or it may go on to complete restoration of function, or it may be arrested at any intermediate stage. Cases have been referred to in which a permanent deformity existed, but the functions of the body and limbs were in no manner disturbed by it. Finally, in one or two cases, secondary fracture has occurred and caused death.

Treatment.—While the indications for treatment are the same as in other fractures—to reduce the displacement and maintain the reduction until repair shall have taken place—they can rarely be efficiently met, and are, moreover, associated with many others affecting the patient's life or comfort.

When a fracture is first received it is important, and especially so if the fracture occupies the cervical spine, that no movement should be communicated to the fragments which might increase their displacement or create a fresh one; the patient should therefore be handled very carefully, and his head and neck should be supported in case of need upon a large firm pillow that will immobilize them. Shaw recommends for this purpose a sac or pillow-case filled with sand. If there is much displacement, an attempt may be made to overcome or diminish it by cautious extension, applied either by the hands or by a weight and pulley, and aided by cushions or pads placed so as to make lateral pressure (coaptation), and frequently shifted so as to avoid sloughing. The gypsum-jacket has been recently employed to support the trunk during repair, and some interesting and successful cases have been reported. Küster,[1] of Berlin, reported four cases at the Congress of the German Surgical Association, in three of which much benefit had resulted. In all, suspension was made under chloroform, and the angle forcibly straightened by pressing it forward until the bone was felt to yield with a snap; then permanent extension (22 pounds) was applied to the head. This was followed by gradual improvement of the paralysis, and was repeated twice. The discussion that followed brought to light the fact that the method had been employed not infrequently (as early as 1862 by von Langenbeck) and with a fair measure of success, but most of the surgeons thought its use should be restricted to the less severe cases. Berkeley Hill[2] has recently reported a successful instance of its use after fracture in the lower dorsal region, and Drs. Hodgen and

[1] Supplement Centralblatt für Chirurgie, 1881, No. 20, p. 33.
[2] Med. Times and Gazette, 1881, vol. i. p. 388.

Ashhurst have used it to give support to the trunk so that the patient could be placed in a chair during the day. I have tried it twice in cases of fracture in the lower dorsal region in adults, but without benefit. In making extension by suspension the patient must be carefully watched and the traction increased very cautiously; in one case I found it necessary to make very limited extension by placing the patient upon a plank and raising him from the horizontal to the inclined position, the shoulders being fixed to the upper end of the plank, and the weight of the lower limbs making the extension. Instead of making the jacket in the usual manner by many turns of a roller-bandage, it is better to take eight or ten thicknesses of gauze of suitable size and shape, soak them in plaster-cream, pass them under the trunk as the patient lies upon the plank, and then fold them around so as to overlap in front while extension is maintained.

Strychnine and ergot, the latter in large and increasing doses, are thought to aid improvement; and electrical stimulation of the muscles may be profitably employed to prevent their degeneration, while the restoration of the functions of the nerves is waited for. Bloodletting and surface irritation are to be avoided.

Operative interference, other than that of extension to overcome displacement, has been limited to the removal of splinters after gunshot fracture and to the removal of the spinous processes and adjoining portions of the arches of one or more vertebræ to relieve pressure upon the cord. So far as is known the first operation of either kind was by Louis in 1762; an officer had received a shot in the back which caused paralysis of the lower limbs and retention of urine. Louis enlarged the wound on the fourth or fifth day, and removed the ball and several loose splinters; the patient recovered, but his legs remained weak and small. Twenty-four similar cases are reported in the Medical and Surgical History of the War of the Rebellion (Part First, Surgical Volume, pp. 455 and 459), of which only ten died. In nine of the successful cases "the spinous process alone or portions of it only were removed, and that the injuries to the vertebral column could not have been of a very serious nature is shown by seven of the patients having been speedily returned to duty or exchanged." "In the five cases of recovery in which portions of the laminæ or of the transverse processes were removed, the results were much less satisfactory, and nearly all of the patients still suffer from serious disabilities."

The conversion of a simple into a compound fracture by incision, in order to remove fragments that press upon the cord or to replace displaced vertebræ, is mentioned in the writings of some of the older surgeons, as far back even as Paulus Ægineta, and is spoken of by some as if it had been actually performed; but the first positively known instance is the one in which Cline,[1] in 1814, performed the operation after fracture of the seventh, eighth, and ninth cervical vertebræ, the spinous processes and adjoining portions of the arches being forced in upon the cord. Dr. Ashhurst[2] has collected forty more or less well-authenticated cases, of

[1] New England Journal of Med. and Surg., January, 1815.
[2] Princ. and Pract. of Surgery, 2d ed. 1878, p. 336.

which only three were said to have been relieved. The propriety of the operation has been discussed with much warmth upon both sides, especially between Sir Astley Cooper and Sir Charles Bell in the early part of this century. Of late years its chief advocates have been Brown-Séquard, Nunneley, and Félizet, while the authors of most of the systematic treatises upon Surgery or Fractures have withheld their approval. While I believe that the danger of the operation has been considerably overstated by its opponents, and that it might be still further diminished by the use of the antiseptic method, still, as in many cases the necessary change in the position of the parts cannot be effected, because the pressure upon the cord which it is desired to relieve is made in front by the inaccessible body of the vertebra, and as the diagnosis must always remain somewhat uncertain and incomplete, I do not believe that surgeons will feel justified in undertaking it except under rare circumstances, such as fracture in the cervical region with a fair probability of finding that the pressure upon the cord is due to a displaced spinous process. In the dorsal and lumbar regions the fracture, even when due to direct violence, usually involves the body of the vertebra, and if pressure is made upon the cord in consequence it is made in front and not behind, and its seat is outside the field of a prudent operation. It is certain that better results have been obtained by suspension and the plaster jacket than by trephining, and if the promise held out by the few cases in which the former method has been tried should be confirmed by further experience there would seem to be no reason to have recourse to the other.

The operation has usually consisted in a long incision in the median line, through which the spinous processes and arches were exposed; the latter were then cut through with saws, trephines, or forceps, and the spinous process lifted out. It has been proposed to accomplish the same result by passing a stout hook through the skin, engaging it in or under the depressed portion, and then drawing upon it until the displacement is overcome, but I am not aware that the attempt has ever been made.

CHAPTER XIV.

FRACTURES OF THE BONES OF THE FACE.

1. Fractures of the Nose.

Under this term we include not only the two nasal bones, but also those upon which they rest, the septum, the nasal process of the superior maxillary, and the nasal spine of the frontal. The fracture may involve one or both nasal bones or adjoining processes; it may be simple or compound, multiple or comminuted; and it may be associated with other fractures of neighboring bones, the most important of which is fracture of the cribriform plate of the ethmoid. In the great majority of cases the fracture is a more or less comminuted one, occupying the lower half of the nasal bones, the main line of fracture running transversely or obliquely, and the fragments are displaced backwards or backwards and to one side, according to the direction of the force that has produced the injury. In rare cases the fracture involves only one nasal bone, with or without displacement of the lower fragment, or there may be dislocation of one or both bones. Gurlt collected three cases of this dislocation or diastasis, two of one bone, and one of both bones. The cases in which the blow has fallen upon the upper portion of the nasal bones and has fractured the cribriform plate of the ethmoid or the nasal spine and adjoining parts of the frontal are rare, and belong among fractures of the skull rather than among fractures of the nose. The perpendicular plate of the ethmoid is so slight and so flexible that it will itself break or bend before it can transmit a fracturing force to the cribriform plate. The cartilages which form the alæ may be broken or torn from their attachments to the bone, and that which forms the lower part of the septum is frequently broken in connection with fractures of the bones themselves.

Dr. Hamilton[1] says that of the twenty-five cases mentioned in his book only fourteen were seen by a surgeon in time to receive treatment, and he urges therefore that the possibility of this injury should always be borne in mind, and that search should be made for it whenever there is reason to suppose that it may be present. The symptoms by which it may be recognized are deformity, mobility, and crepitus. The swelling of the soft parts, which appears promptly and is usually sufficient to completely mask the outline of the parts, may make the diagnosis difficult, and the sensitiveness of the mucous surface of the nostrils is such that any exploration from that side meets with many objections and perhaps the positive refusal of the patient to allow it. Still, unless the swelling is very great and the displacement very slight the deformity

[1] Loc. cit., p. 101.

will be recognized; and indeed the ease with which it is recognized increases the desirability of reducing it, for any irregularity in a member so prominent as the nose is certain to attract attention, and may become the source of much annoyance to the unfortunate patient.

Other symptoms which may be present but which are by no means pathognomonic, are free bleeding from the nose, and occasionally emphysema of the eyelids and face. Bleeding is often severe and sometimes recurrent and difficult to arrest, but rarely endangers life. Emphysema generally has its origin in an effort of the patient to blow his nose; the air is forced into the subcutaneous cellular tissue through a rent in the mucous membrane and periosteum and spreads promptly to the eyelids and sometimes over the rest of the face.

It is so important that a fracture should be recognized and its displacement corrected, that an anæsthetic should be used if a thorough exploration cannot be made without its aid, and the surgeon should spare no pains to satisfy himself as to the condition and position of the bones. The examination cannot prudently be postponed, for the bones of the face unite promptly, and more than once it has been found impossible to correct a displacement after eight or ten days had elapsed; firm union may be expected within a fortnight or three weeks.

An occasional symptom, when the fracture has extended into the adjoining portion of the superior maxillary bone, is obstruction to the flow through the lachrymal duct in consequence of its inclusion in the line of fracture. Another and more common one is the difficulty or impossibility of breathing through the nose, the result of inflammatory swelling of the mucous membrane: and, finally, in the comminuted fractures that are or have become compound, suppuration may be maintained for weeks or months until all the necrosed fragments have worked their way out or have been removed. It occasionally happens, too, that after a simple fracture a tendency is manifested towards inflammatory complications in the neighborhood, abscesses form in and about the nose, portions of bone or cartilage become necrosed and are exfoliated, and a constant purulent discharge from the nostrils is maintained by carious bone or persistent ulcers.

The prognosis as regards life is favorable, except in those cases in which the skull is at the same time broken, and in those few others in which recurrent hemorrhages, of which no satisfactory explanation is given, show themselves. But as regards the avoidance of deformity the outlook is not so favorable, because it is not always easy to recognize or correct a displacement through the swollen tissues, and the persistence of even a slight one is likely to be a very noticeable blemish. In those cases in which there has been loss of substance or in which the nasal bones remain depressed to the level of the superior maxillary bones the deformity is extreme.

The treatment consists mainly in the reduction of the displacement, for it is seldom possible to apply any apparatus or dressing that will prevent a recurrence of the displacement if there is any tendency towards it. The reduction is accomplished by pressure made from within the nostril, aided by manipulation or modelling of the fragments on the outside. The interval between the septum and the side of the nose at the

part of the nostril corresponding to the nasal bone is small, so small that it will not ordinarily admit an instrument as large as a female catheter, and therefore it is useless to attempt reduction by passing the finger into the nostril; a small strong instrument, such as a steel director, must be used, one that is small enough to work within the narrow space next the nasal bone, and strong enough to transmit considerable pressure. The fingers of the left hand placed upon the nose serve to guide the instrument and to recognize the degree of reduction that has been obtained. Ordinarily there is but little tendency to recurrence of the displacement, except when the fracture is comminuted and the septum badly broken; the only forces that tend to change the position of the fragments are the swelling of the external soft parts, and the pressure of the air when the patient seeks to clear his nose by snuffling or blowing. The older surgeons attached much importance to dressings of adhesive plaster covering the nose and designed apparently to keep the bones in place by holding up the skin. It does not appear that they serve any other purpose than that of protecting the parts from further violence.

The idea of supporting the fragments by pressure from within the nostrils suggests itself so readily that it is not surprising to find recorded many instances and several varieties in the methods of its use. The simpler ones consist of plugs of lint crowded into the nostrils, with or without tubes to permit breathing; the more elaborate ones are arrangements of rods supported by straps crossing the upper lip, and capable of adjustment in length and direction within the nostril so as to hold the fragments in place; they are said to have been efficient in some difficult cases. On the other hand, I can find no evidence that the plugs of lint serve any useful purpose. I have had no experience with them, but I should imagine their adjustment to be difficult, their fixity uncertain, and their presence the cause of much discomfort. Instead of trying to prevent displacement by such means I should confine my efforts to overcoming the displacement once or twice a day, so long as it recurred, trusting to the rapidity of repair to soon render such interference unnecessary.

Dr. L. D. Mason[1] recommends a method by which good results have been obtained in four cases of extensive fracture. He transfixes the nose, after reduction, just below the fragments with a stout needle and steadies the pieces with a strip of rubber or adhesive plaster crossing the bridge and caught upon the ends of the needle. The needle is left in place for about ten days.

Emphysema needs no special treatment; it tends to disappear promptly and spontaneously by absorption. Swelling may be such as to require the use of cold applications or of leeches, and bleeding may be so severe as to require plugging of the nostrils. The patient should be cautioned against making any forcible inspiratory or expiratory acts, especially snuffling and hawking, lest he should displace the fragments or occasion a fresh hemorrhage or emphysema.

For the details of the methods by which deformity due to a badly united fracture may be relieved, the reader is referred to works upon

[1] Annals of the Anat. and Surg. Soc., Brooklyn, vol. ii. p. 107, and vol. iii. p. 81.

reparative and operative surgery. In some cases it is sufficient to separate the cartilages of the alæ from the nasal bones by a subcutaneous incision and to divide the septum; in others the displaced bones and the septum need to be broken with stout forceps, and in one case in which this plan failed, Dr. R. F. Weir obtained an excellent result by cutting down upon the side of the nose, dividing the bone with a chisel, and maintaining it in the desired position for a few days by a rod attached to a band about the head.

2. Fractures of the Malar Bone and Zygoma.

Isolated fractures of this bone are rare, and, so far as can be inferred from the small number of cases in which a direct examination has been possible, single fractures are rarer than multiple ones, and the rarest is that which is almost a simple diastasis, a separation at the sutures with some splintering. Partial fractures involving the lower and outer portion of the bone or the margin of the orbit have been observed, and also single fractures of the frontal and zygomatic processes, extending possibly into the bones with which they articulate. In most cases there is depression of the entire bone with fracture of the malar process of the superior maxilla and crushing of the anterior wall of the antrum, the malar bone being displaced inwards towards the antrum or sometimes backward into the zygomatic fossa. Pure diastasis of the malar bone probably does not exist; it has never been demonstrated by autopsy, and attempts to produce it upon the cadaver have always resulted in more or less fracturing. Gurlt has collected three cases described as diastasis, in which the lines of separation apparently followed those of the sutures very closely. The principal peculiarity in these cases is in the displacement, which instead of being inward towards the antrum, as is most common after fracture, was downward and outward in one, and upward and inward towards the orbit in another; and in the third, in which the zygoma was not broken or separated, the frontal process of the malar bone was displaced forward and a little inward, and there was a depression in the lower margin of the orbit at the junction of the malar and superior maxillary bones.

Fractures of the *zygomatic arch* alone have been caused by external violence acting from without inwards, as a fall, a blow of the fist or a ball, and in two cases from within outwards, the patient having fallen forward upon a stick held in the mouth. Hamilton's experiments upon the cadaver indicate that the fracture usually takes place in the temporal portion of the zygoma, a little behind the suture. The displacement follows the direction of the fracturing force.

The symptoms upon which the diagnosis must be made are deformity, mobility, and crepitation. Unless there is much inflammatory swelling or extravasated blood, the deformity, which consists usually in a depression or flattening of the cheek just below the outer half of the eye, can be recognized by sight and touch, and the irregularity of the line of fracture can be readily felt on the margin of the orbit, or, if it extends to the malar process of the superior maxillary bone, on the under and anterior surface of this process by the finger within the mouth. Mobility

and crepitation are perceived more rarely; the latter can be sometimes produced by the movement of the jaw.

Anæsthesia or a sense of formication in the cheek, nose, upper lip, and gum of the corresponding side is sometimes observed, and is due to an extension of the fracture along the floor of the orbit, involving the infra-orbital canal and tearing or bruising the superior maxillary nerve. This symptom may be associated with an extravasation of blood in the posterior part of the orbit sufficient to force the eye forwards and showing itself also under the conjunctiva and in the eyelids. Bleeding from the mouth or nose is occasionally seen as the result of the extension of the fracture through the mucous membrane of the mouth or antrum.

When the fracture involves the zygomatic arch, and the fragments, as is usually the case, are driven inwards, movement of the jaw may be difficult or impossible, either because the masseter has been injured, or because the depressed fragments of the arch are forced against the coronoid process of the inferior maxilla, or into the tendon of the temporal muscle. In one case the tip of the coronoid process was broken off by the same blow that fractured the arch. Swelling, discoloration, and pain are the natural and constant results of the fracture and the bruising of the soft parts.

The natural course of these fractures is towards rapid repair without excessive callus, and with gradual disappearance of any difficulty that may exist at first in the movements of the jaws. It is seldom possible to reduce the displacement completely, because, as has been said, it is generally inwards and there is no way of acting very efficiently upon the bone, except through a wound of the skin. The attempt must be made to move the bone in the desired direction by engaging the end of the thumb or finger under it in the zygomatic fossa, introducing it through the mouth if the cheek is swollen. It has been proposed, and occasionally practised, to cut down upon the bone opposite the zygomatic process, divide the fascia overlying the masseter muscle, pass a stout hook under the process, and raise the bone by drawing upon it, or to make a smaller incision over the body of the bone and screw an elevator into it, by which it could then be raised. If the incision is so made as not to transform a simple into a compound fracture there can be no serious objection to the plan whenever the displacement is sufficient to cause much disfigurement, and there is even less reason to refuse to use the existing wound of a compound fracture for the same purpose.

Inward displacement of the zygomatic arch cannot be directly acted upon except through the skin. Ferrier raised the bone in a simple fracture, and Dupuytren in a compound fracture, in this manner. Considerable suppuration followed in the latter case, but the patient made a good recovery. In only one of the recorded cases has the displacement interfered seriously and for any length of time with the movement of the jaws; in this one the difficulty increased steadily for some time until the patient could barely separate the teeth, and then one morning while yawning he felt something snap, and the motion of the jaw at once became and remained free.

Outward displacement of the same portion of the bone can be readily

corrected by pressure, and that of the body of the bone can usually be corrected almost entirely by the same means. No dressings are needed other than those designed to favor the repair of the bruised soft parts.

3. Fractures of the Superior Maxilla.

While the body of this bone, protected as it is by outlying processes and other bones, is rarely fractured, its own processes are not infrequently broken or involved in the fractures of those bones with which they are continuous. Thus, a blow upon the nose breaks not only the nasal bones but also the nasal process of the superior maxilla, and a blow upon the malar bone may force in the anterior wall of the antrum on which it rests. The fractures are always produced by direct violence, and present, consequently, considerable variety in their extent and the parts involved. The alveolar process may be broken off in part or entirely by a blow received on it or on the teeth. A blow received in front, at or below the level of the nostrils, may produce a horizontal line of fracture separating the alveolar and palatal processes from the body of the bone, and including also the pterygoid plates. Falls from a height have caused a vertical line of fracture or diastasis between the two bones along the median line of the mouth, extending even through the soft palate and associated with fracture of the malar or nasal bones. Fractures of the roof of the mouth are usually multiple, and the most severe ones appear to be those caused by a blow received upon the malar bone which has crushed in the wall of the antrum. In a case of this kind mentioned by Hamilton, an attempt to remove a loose molar tooth "brought down several teeth and the whole floor of the antrum," attached to which was found, after its removal, a considerable portion of the pyramidal process of the os palati. Fractures of the alveolar process, even with much displacement and mobility, present but little gravity, for they heal rapidly and without necrosis.

It occasionally happens that one or both bones are driven in with multiple and comminuted fracturing of them and of the adjoining ones. The earliest known case of the kind was reported by Wiseman, and has been extensively quoted. The upper jaw was driven in so far that the finger could not be introduced between the palate and the posterior wall of the pharynx. Wiseman inserted a blunt hook through the mouth and easily drew the bone forward into place; as, however, the displacement recurred very easily he left the hook behind the palate and had it drawn upon constantly by the patient or his friends until consolidation had taken place. Quite a number of similar cases (Gurlt has collected upwards of twenty) have been reported, all the result of great violence, either by falls from a height or the passage across the face of a heavy wagon, or a violent blow. In one case the bones of the face were so movable that they moved up and down when the patient swallowed, as if they were restrained only by the skin. In most of them the patients recovered, and it is worthy of remark, that notwithstanding the degree of the violence and the extent of the injury, it seldom happens that the fracture involves the skull. The reason lies apparently in the direction in which the fracturing force is applied, a direction outside of, and more or less parallel to the surface of the skull, and not in the line of one of its

diameters. The bones of the face are, as it were, torn off the skull rather than driven back upon it.

Very extensive mutilation of the face has been caused by gunshot wounds, especially in attempts at suicide when the muzzle of the gun has been placed within the mouth, but it is rare for ordinary violence to lead to much loss of tissue. Malgaigne speaks of the following case as unique in this respect in his experience. A lad was kicked in the face by a horse; the superior maxillary, nasal, and palatal bones were extensively comminuted, and the skin torn and bruised. Recovery took place, but with much deformity. The nasal bones, the anterior portion of the alveolar arch, and the greater part, if not all, of the hard palate had disappeared. There was no longer either nose or mouth; the lips were united by a firm cicatrix, and the mouth and nostrils were represented by an oval opening between the nasal processes of the superior maxillæ. Through this opening the patient breathed, spoke, drank, and ate.

The diagnosis of fracture is ordinarily made without any difficulty, since large portions of the bone are open to direct examination with the finger through the mouth and on the cheek. Irregularity of outline, mobility, displacements, and crepitation can be readily recognized. In some few cases where there was no displacement the diagnosis has been in doubt, and Guérin[1] has pointed out a symptom which might be useful under such circumstances. It has been said that the pterygoid apophysis is always broken when the line of fracture crosses the jaw horizontally between the alveolar process and the malar bone, and Guérin found that pressure with the finger upon the inner plate of this process caused pain and sometimes showed mobility when there was no other sign of fracture. It is, however, extremely difficult to recognize the extent of the fracture in those comparatively rare cases in which the bones of the base of the skull are likewise broken, because they are removed from the range of direct examination. As a rule, the diagnosis can be completed only after the lapse of the period of time which is necessary to the appearance of the grave symptoms to which such extension of the fracture may give rise.

Repair in cases of average severity takes place in from thirty to forty days with a scanty formation of callus, and not infrequently in less time. The vitality of the bone is exceptionally great, hence the rule laid down by Malgaigne and some of his predecessors, and repeated by all subsequent writers, to leave every fragment that is not absolutely and entirely detached. Although the rule is a sound one, it occasionally happens that fragments become necrosed, and have to be removed. This is thought to happen more frequently with fragments of the alveolar border than with any others.

Displacement is seldom noticeable after repair is completed, except in the nose, but it usually exists to a greater or less degree, and the ingenuity and the patience of the surgeon are often severely taxed to overcome the constant tendency to the recurrence of the displacement. Salivation is often profuse, and the discharge offensive. Division of the lachrymal canal by the fracture may lead to its obliteration.

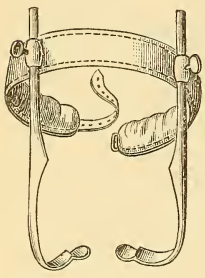
Displacement of the entire bone may be treated as in Wiseman's case, or the retention may be aided by securing the lower jaw against the

[1] Archives Générales de Médecine, July, 1866, vol. ii. p. 5.

upper one, with or without the intervention of interdental splints or moulds of gutta percha, or metal shaped to fit the teeth and alveolar arch. Lateral pressure cannot well be made upon the cheeks to overcome separation along the median line of the palate, but fortunately it is not always necessary. In Simonin's case, quoted by Malgaigne, the gap began to contract spontaneously by the tenth day, and was completely closed by the thirty-third, with no other displacement than a slight difference in level between the two halves. In another case, quoted by Hamilton, the gap was large enough to admit the little finger, and was still open six weeks after the receipt of the injury.

After fracture of the alveolar process the fragment should be carefully readjusted and fixed by wiring the teeth to the adjoining ones, or by a mould of gutta percha or metal. Agnew says he has used for this purpose with great advantage a piece of cork with grooves cut in its upper and lower surfaces to receive the teeth of both jaws. The reduction is made, the cork inserted, and the jaws firmly bound together. No attempt should be made to remove the corresponding teeth, for not only are the chances in favor of their becoming firm again in their sockets, but the attempt to draw them, even if they are loose, may materially increase the mischief done by the fracture, as in Hamilton's case quoted above, in which such an attempt caused the loss of the entire floor of the antrum.

Fig. 142.



Intra-buccal splint for fracture of the upper jaw.

The gutta percha or metal moulds may be held in place by binding the lower jaw against it after it has been fitted to the upper one, or by an apparatus similar to one devised by Graefe for the purpose, and shown in figure 142. If the splint is to be supported by the lower jaw it should be so constructed that an interval will be left through which food can be given and the mouth cleaned.

4. Fractures of the Inferior Maxilla.

Fracture of the inferior maxilla occurs more frequently than that of any other of the bones of the face. It is rare in childhood and old age, most frequent between the ages of 20 and 30, and is apparently more than ten times as common in males as in females.

Gurlt collected 143 published cases in which the character and position of the fracture were described with sufficient accuracy to allow of their use as statistics; of these 80 were single, 49 double, and in 14 there were three or more lines of fracture. Of 75 single ones (excluding 5 in which the fracture was limited to the alveolar process) the fracture occupied the median line in 25, the region of the incisor teeth in 22, that of the back teeth in 15, behind the teeth in 8, and the condyloid process in 5. In 35 double fractures both halves of the bone were broken 20 times, and at points on the two halves corresponding closely with each other; one side alone 8 times, and the median line by one of the fractures 7 times. One or both of the condyloid processes were broken in several of the multiple fractures. These figures show that, exclusive

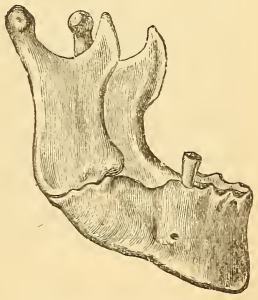
of partial fractures of the alveolar border, which are very common, and often caused by the drawing of a tooth, the most frequent seat of fracture is at or near the median line, and that single fracture of the ramus, or of the alveolar or condyloid process is comparatively rare. They differ materially from the estimates made by various writers, but as the latter differ quite as much among themselves, and appear to have spoken in most cases from general impressions rather than from figures, the preference should be given, I think, to Gurlt.

Double fractures of the lower jaw are relatively more common than those of other bones, while multiple and comminuted ones are rare. Compound fractures are common, both because the gum overlying the fracture is frequently torn, and because the lip and skin are often involved in the direct injury that has caused the fracture. The fracture is complete or incomplete, the latter rarely except when the alveolar border alone is involved. Cases are reported in which a portion of the body of the bone adjoining the alveolar border has been broken off; and at least one case (Hamilton) which appears to have been an infraction in the line of the outer incisor tooth.

The line of fracture in the body of the bone is usually vertical or nearly vertical; at the angle or in the ramus it is oblique or transverse. At the median line there is but little displacement, if any; but, when present, it may be in either of three directions: a difference in the horizontal level of the edge of the teeth, a displacement forwards and backwards of the fragments upon each other with lateral overriding, or a lateral separation of the two. In the fractures between the median line and the canine tooth the line is still much more frequently vertical than oblique; but displacement is the rule, although no one form of it seems to be more common than the others. Between the canine tooth and the angle of the jaw it is either vertical or inclined backwards and downwards, and usually, instead of crossing the bone from without inwards at a right angle to the surface, it is inclined backwards and inwards, so that the anterior fragment is lengthened on the inner side and the posterior fragment on the outer side. The inferior dental nerve is crossed by this fracture, as it lies within the bone, and is sometimes torn or bruised.

Fracture behind the teeth is comparatively rare, only eighteen cases being contained in Gurlt's statistics, and it is frequently double or multiple or associated with other fractures. When the fracture lies at the junction of the body of the jaw and the ascending ramus, it is usually oblique, running from behind the last tooth backwards and outwards towards the angle of the jaw; but it may be vertical. Displacement is usually slight or lacking, the parts being kept well together by the masseter and internal pterygoid muscles.

Fig. 143.



Fracture of lower jaw behind the teeth.

Fracture of the condyloid process is usually accompanied by other fractures of the same or other bones of the face, and may be produced by a blow either upon the chin or upon the side of the jaw near the joint. The line of

fracture passes through the neck, and the few specimens furnished by autopsies and museums do not show a greater frequency at any point or in any direction than at any other.

Dr. Will[1] reported a case with specimen, the patient having died in consequence of an associated fracture of the pelvis. The line of fracture was oblique backward and downward from the bottom of the sigmoid fossa. The symptoms were few, but the nature of the injury was quite evident. There was slight deviation of the chin towards the affected side, abnormal lateral mobility, and indistinct crepitus. Examination by the mouth revealed displacement of the condyle upward and forward by the action of the external pterygoid muscle. Dr. Will adds that, according to Heath, there are only six examples of this fracture in the London museums. Cases have been mentioned by Soranus, Desault, Ribes, Bérard, Houzelot, Bichat, Packard, Watson (of N. Y.), and an incomplete one of both condyles by Verneuil.

Fracture of the coronoid process is exceedingly rare. Gurlt's collection contains two cases and a reference to a third. In one, both coronoid processes, both condyles, and the symphysis were broken by a fall from a height; in the second,[2] the coronoid process and the condyle were broken by a fall from a loft. The patient died of delirium tremens. In the third case, the zygoma and malar bone had been driven in upon and had broken off the tip of the coronoid process. There was extensive fracturing of the bones of the face and of the base of the skull.

A portion of the alveolar process with the teeth in place is sometimes broken off. The size of the piece varies within wide limits, and the displacement is habitually inwards. In one or two entirely exceptional cases a similar piece, including a portion of the body of the bone, has been broken off.

In double fractures, the intermediate piece is almost invariably drawn downwards and backwards by the unopposed action of the muscles of the neck which are attached to it.

Comminuted fractures, except as the result of gunshot wounds, are comparatively rare; double and treble fractures are less so; and one case is on record in which there were five distinct and separate lines of fracture.

In three of Gurlt's cases the autopsy showed rupture or crushing of the inferior dental nerve, and in two the external ear was injured, by fracture of its bony wall in one case, and by rupture of its cartilaginous portion in the other.

The most frequent cause of fracture, exclusive of partial fractures produced by attempts to draw a tooth, is violence received upon the chin; fracture by pressure upon the sides is much less common, the other occurring thrice as frequently. Hamilton mentions a case in which a double fracture was produced in a young woman by the grasp of her husband's hand. Fracture of the condyloid process may be produced in either of the same two ways—a blow upon the chin or upon the cheek. Examples of fracture of the coronoid process are too rare, and too little is known concerning them to explain their mode of pro-

[1] Lancet, 1882, vol. i. p. 100.

[2] Lancet, 1860, vol. ii. p. 536.

duction. The position of the bone is so sheltered that it can hardly be broken by direct violence except after fracture of the zygoma, and, although its fracture by the contraction of the temporal muscles has been alleged, there are no facts to demonstrate it.

The objective symptoms of fracture of the lower jaw are the same as those of other fractures: abnormal mobility, crepitation, displacement. The bone is so accessible to the touch both within and without the mouth that irregularities in the outline of its body can be easily recognized by the fingers and sometimes by sight. The teeth show differences in level, vertically or antero-posteriorly; those which adjoin the fracture are usually loosened and may be entirely displaced; in one or two cases a tooth has slipped or been driven in and lodged between the fragments. Mobility and crepitation are detected by manipulation. When the fracture is situated at or above the angle of the jaw its recognition is by no means so easy; by passing the finger within the mouth along the inner and outer surfaces of the ramus, irregularities of outline and localized points of pain may be recognized.

The degree and direction of the displacement vary much. As a rule, when the fracture is single and not in the median line, the anterior fragment tends towards the inside of the mouth, and this displacement is favored by the obliquity of the line of fracture which, as above mentioned, usually leaves the anterior fragment longer on the inside than on the outside. The causes of the displacement have been the subject of some discussion. It has been shown, on the one hand, that the usual displacement is produced on the cadaver by the simple action of the fracturing force; and, on the other, by the recurrence of the displacement after correction, that the action of the muscles is also able to produce it. The differences that have been noted by various observers corresponding to different positions of the fracture have not proved constant, and as their causes appear to have been incidental and varying, they do not require examination.

In a case observed by Pierson,[1] a double fracture was occasioned by the passage of a wheel across the jaw, and the intermediate portion of bone, with the tongue, dropped back into the mouth and throat so as to nearly cause suffocation. The patient contrived to draw the tongue forward with a spoon and prevent suffocation until the surgeon secured the fragment by wiring the teeth. Similar consequences have followed resection of the median portion of the jaw.

Pain on pressure and on movements of the jaw is a constant and well-marked symptom, and may be produced also by deglutition. It may be extremely severe, and may give rise to nervous and tetanic symptoms of much importance when it is due to injury of the inferior dental nerve within its canal. Usually injury to this nerve is shown only by anæsthesia of the lower lip and chin on the affected side, usually temporary, but occasionally permanent. Malgaigne denies the frequency of such injury to the nerve, and says that he has never personally met with an instance of it.

[1] American Journ. Med. Sciences, 1841, p. 186.

There are no recorded clinical facts indicating the symptoms of fracture of the coronoid process.

Fracture of the condyloid process was first studied by Desault and Bichat, and but little if anything has been added to our knowledge of the subject since their time. The symptoms are pain increased by motion, diminished mobility of the jaw, often crepitation on manipulation, irregularities in the region of the condyle, the ease with which the condyle can be pushed forward into the zygomatic fossa, its failure to share in the movements of the jaw, and its almost constant displacement upwards and forwards by the contraction of the external pterygoid. Ribes pointed out an additional symptom which is sometimes present, deviation of the chin towards the affected side. This is effected by the displacement of the ramus upwards and backwards on the outer side of the condyle and neck, and the more easily if the fracture is a double or multiple one. Gurlt quotes the description of a specimen of this kind from a work by Bonn, published in 1785. The condyle was united by a bony callus to the ramus just above the orifice of the dental canal.

Swelling of the gums, face, and glands follows promptly upon the injury and is often increased by the direct bruising of the soft parts themselves; the secretions of the mouth, increased in quantity by the irritation, mingle with the pus that comes from the fracture if compound or from the ulcers produced by the stomatitis, decompose, and cause an offensive odor that can scarcely be kept under control even by the most careful attention. Abscesses may form and open within the mouth or upon the sides of the jaw or the neck below it; they are almost invariably associated with the presence of detached splinters or the exfoliation of portions of the jaw which require, of course, to be removed before a permanent cure can be obtained. Small fragments may long escape recognition, and the only indication of their presence may be a fistula; larger fragments force themselves promptly upon the surgeon's attention by the profuseness of the discharge and the amount of local irritation. In a case reported by Ancelon,[1] of double fracture of the body of the lower jaw, the fracture being on one side two centimetres, and on the other three centimetres in front of the insertion of the masseter, the entire portion on each side behind the fracture became necrotic. Six months after the accident the left ramus was cast off spontaneously, and the right one was removed by the surgeon. The central piece was preserved, and recovery took place with slight disfigurement. In a case mentioned by Desault, fracture of the neck of the condyle was followed by necrosis and elimination of the fragment, and in another, mentioned by Malgaigne,[2] Monteggia saw suppurative periostitis, total necrosis, and death follow fracture caused by a blow with a stick. As a rule, however, the vitality of fragments of the lower jaw is great, and necrosis, except of limited points of the alveolar border, is uncommon.

Simple fractures unite in from thirty to forty days, and even when there has been a considerable loss of bone by splintering or necrosis, the final result may be a very good one, in this sense, that the jaw is

[1] Gaz. des Hôpitaux, 1854, p. 550. Quoted by Gurlt.
[2] Loc. cit., p. 388.

strong enough to support artificial teeth in the place of those that have been lost by the accident, is sufficiently regular in form to avoid deformity, and is free in its movements.

Failure of union, pseudarthrosis, is rare. Gurlt's statistics contain only two cases which can be properly considered such, and they were both cured by operation. It is more common after gunshot fracture with much loss of substance by elimination of splinters, and may interfere with mastication. In a few cases union in a faulty position has required an operation to correct the deformity or relieve the functional disability.

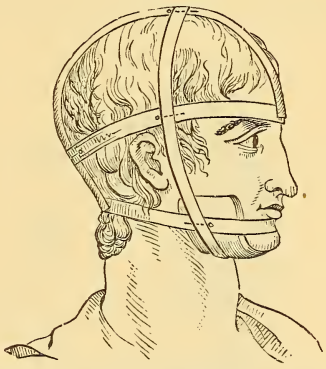
The prognosis is a relatively favorable one ; the probabilities are that union will take place promptly, that no serious complications will arise, and that no important deformity or disability will remain. Danger to life may come from two quarters : the proximity of the bone to the cranium carries with it the possibility of associated injury to the brain or to its case ; retention of pus in a compound fracture in communication with the cavity of the mouth exposes to the grave danger of absorption of the decomposed secretions and, if the displacement and laceration are great, to the burrowing of the decomposed pus along the deeper planes of the neck into the anterior mediastinum.

Treatment.—Displacement following fracture of the body of the jaw can usually be readily overcome by the pressure of the thumb and fingers upon the teeth and the lower border of the bone; in some cases

Fig. 144.

Barton's bandage for fracture of the lower jaw.

Fig. 145.



Gibson's bandage for fracture of the lower jaw.

the interlocking or wedging of the smaller pieces or of displaced teeth, may render the reduction impossible until after they shall have been removed, and in a case reported by Buck[1] to the N. Y. Pathological Society in which the bone was broken very obliquely, the displacement, which amounted to about half an inch, could not be overcome except by the division of the soft parts including the lip and the removal of the sharp end of the anterior fragment. In another case reported to Dr. Hamilton, by Dr. J. H. Packard, it was found necessary to divide the

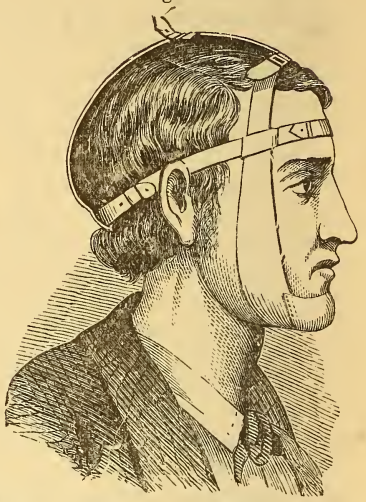
[1] Quoted by Hamilton, loc. cit., p. 132.

attachments of the muscles to the lower border of the bone at the symphysis to prevent recurrence of the displacement.

Fig. 146.

Garretson's bandage for fracture of the lower jaw.

Fig. 147.



Hamilton's bandage for fracture of the lower jaw.

In simple cases where the tendency to displacement is slight it is sufficient to immobilize the lower jaw by binding it against the upper one with a bandage that passes under the chin and over the head and is prevented from slipping by another carried over and around the occiput. Different forms of bandages, which can be used also in connection with interdental splints, are represented in the adjoining figures (figs. 144 to 148).

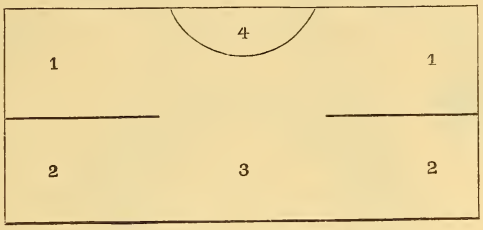
Fig. 148.

Four-tailed bandage for fracture of the lower jaw.

Splints are applied either to the front and under surface of the jaw outside the mouth, or to the teeth, or the inner surface of the jaw, and two kinds are sometimes used in combination. Outside splints are available only in cases in which there is not much tendency to displacement and in which the lateral pressure of a simple bandage would cause the fragments to override in one direction or another. They may be made of leather, pasteboard, gutta percha, or plaster of Paris, and consist essentially of a cup-shaped piece embracing the chin and extending nearly to the angle of the jaw on each side, and to the fold of the neck below. A simple method of making one in pasteboard or gutta

percha, as described by Dr. Agnew, is represented in figures 149 and 150. A piece of the material chosen, 4 or 5 inches long and 2½ inches wide, is divided longitudinally along its centre for one-third of its length

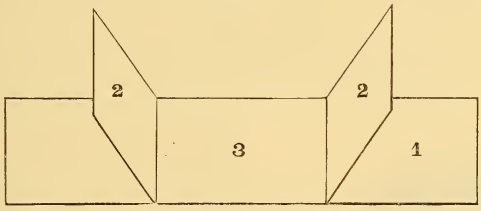
Fig. 149.



Pasteboard splint for fracture of the lower jaw.

at each end. The halves are then bent at a right angle, the ends 2, 2, turned in, and the other ends, 1, 1, turned up against them. The chin

Fig. 150.



The same, partly folded.

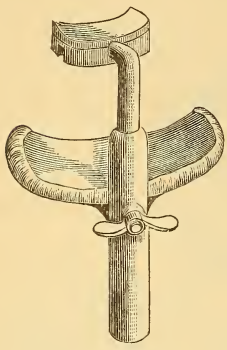
fits in behind the part marked 3 in the figures. It may be necessary to cut away a portion from the opposite edge (4) to make it fit at the throat.

Interdental splints are made of metal, gutta percha, or vulcanized rubber; they are fitted to the crowns of the teeth of both fragments after reduction of the displacement, and are held in place either by binding the jaws together with an outside bandage, or by braces connecting the splint with a pad under the jaw (fig. 151), or by a special arrangement of lateral braces as in Kingsley's apparatus (fig. 152), or by fastening them to the teeth with wires. Some are fitted only to the broken jaw and are intended only to immobilize the fragments on each other; others are fitted to both jaws and enable the upper one to be used as a splint for the lower. Those of which the one represented in figure 151 may be considered the type, give the least firm support and often cause much discomfort by the pressure of the pad under the chin, especially if the soft parts are bruised and swollen. The upper portion of the apparatus is a grooved metal plate fashioned to the teeth as accurately as possible and designed to overlap the line of fracture; the lower portion is a pad capable of adjustment at any desired point along the upright bar.

Gutta-percha splints may be made either of thin strips or of thick

lumps or wedges. The former have a length of three or four inches, for they are intended to overlap the fracture, and a breadth sufficient to overlap the crowns of the teeth from gum to gum; they are softened by immersion in hot water, moulded to the teeth, cooled as rapidly as possible, taken off and trimmed suitably. Then the splint is reapplied and the jaws bound together. If the tendency to displacement is slight the bandage may be loosened during the day to allow the introduction of liquid food, or a wedge may be kept between the jaws so as to create an interval to be used for this purpose, or advantage may be taken of the absence of teeth, especially from the upper jaw. Dr. Hamilton refers also to a method of fastening the splint employed successfully by Dr. J. S. Prout. A plate of gutta percha was moulded to the upper surface of the teeth on both sides of the fracture and secured by wires previously attached to the teeth. This method allows the mouth to be opened. In another case quoted by Gurlt[1] two fragments of the alveolar border carrying eight teeth were secured by a splint of sheet lead moulded to the teeth and fastened down by silver wire, the ends of which were brought out under the chin by means of a needle and tied over a roll of plaster. The wire caused no irritation and was left in place forty-seven days.

Fig. 151.



Splint for fracture of the lower jaw.

Fig. 152.

Kingsley's splint applied.

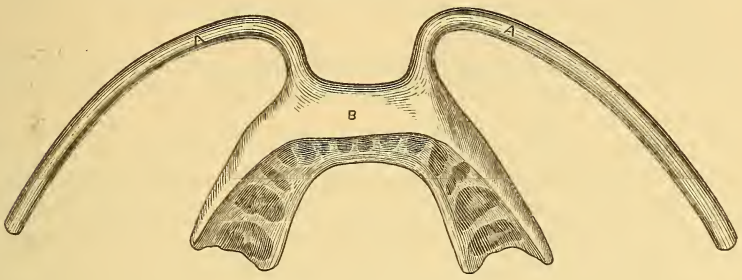
Gutta-percha wedges were introduced by Dr. Hamilton to meet a double indication, that of fixing the fragments securely and of allowing the easy introduction of food. Two pieces of gutta percha of suitable size are softened and formed into wedges and introduced between the jaws, the edge of the wedge directed backward. The jaws are closed upon them, the fragments pressed up until the lower border of the jaw is straight, and the wedges moulded to the sides of the teeth above and below. As soon as the gutta percha has hardened it is removed, trimmed suitably, and reapplied, and the jaws are bound together with a bandage.

Vulcanized rubber is a valuable substitute for gutta percha in some difficult cases, but its employment requires special skill and experience which are found usually only among the dentists. Casts of one or both jaws are first taken in wax; from

[1] Loc. cit., vol. ii. p. 393.

these plaster models are made, and upon these latter the splint. Figures 152 and 153 show the splint as made by Dr. Kingsley, of New York,

Fig. 153.



Kingsley's interdental splint.

with attached bars by which the splint and jaw can be bound firmly together, the bandage passing from one bar to the other underneath the chin.

Another method, which dates back to Hippocrates (see page 187), is to fasten together the teeth on opposite sides of the fracture by thread or wire. In some cases this answers the purpose, but more frequently the wires break, the teeth become loose, and the jaws sore. If used, two or three teeth on each side of the fracture should be included in the loops.

The teeth have been wired together also in other ways to prevent displacement; thus, the lower jaw has been immobilized against the upper one by binding corresponding teeth together, or by fastening a back tooth of the lower jaw to a front tooth of the upper jaw, for example, or one on the left side to another on the right side. In at least one case, where a sufficiently firm hold could not be got by wrapping the wire about the teeth, the latter were perforated with a drill and the wire passed through the holes.

In a few cases of compound fracture the bones themselves have been drilled and wired together as in operations for pseudarthrosis.

Gurlt[1] quotes two cases in which displacement inward was overcome by a metal apparatus fitted to the inside of the jaw and opposing the displacement by a screw or a spring. In each case the fracture was on the side of the jaw.

Repair takes place so rapidly that, except in compound fracture with much suppuration, there is rarely any tendency to displacement after the tenth day, and therefore the discomforts incidental to the continuous closure of the jaws do not need to be borne for any great length of time. If the importance of the case warrants it, if the displacement can be prevented only by keeping the jaws constantly in contact with each other, the patient can be fed through a tube passed behind the last molar tooth, or through the nose. It has been shown of late that a tube through which the patient can be exclusively nourished can be worn permanently

[1] Loc. cit., vol. ii. p. 439.

in the nostril and œsophagus, without inconvenience, for several months. Krishaber has done this in one case with a gum œsophageal tube, and Verneuil with soft rubber catheters in several cases, for days at a time, after operations upon the mouth.[1] There seems to be no reason to doubt that the same measure could be employed successfully, in case of need, after fracture of the jaw.

Cleansing and disinfecting washes containing chlorate of potash, borax, or alum will be found to add much to the comfort of the patient whenever they can be used.

After fracture of the neck of the condyle the tendency is to the displacement of the condyle forwards by the traction of the external pterygoid muscle, and as the fragment is too small to be acted upon directly by any dressing this tendency, if manifested, cannot well be overcome. The treatment, therefore, is to reduce the displacement if it exists, and then to immobilize the jaw after having pressed it backward and upward to interlock the fragments. Ribes reduced the displacement by passing his forefinger into the mouth and along the inner side of the ascending ramus until he reached the condyle and was able to press it back into place. Fountain, of Iowa, obtained a good result by drawing the jaw well forward and wiring the teeth together, so as to maintain the position.

Fracture of the coronoid process is not open to any treatment except immobilization.

Fractures of the alveolar border are best treated, like fractures of the body, by immobilization after careful reduction of the displacement, and it is advisable not to make haste to remove loose or semi-detached teeth. They may become firmly adherent again, or, if this should fail, they may be removed subsequently without having caused any serious trouble or delay.

Delayed union and pseudarthrosis are to be treated by the removal of the cause, if any definite local one exist, or by operative interference, freshening of the surfaces of fracture, and wiring of the fragments.

[1] Bulletins de la Soc. de Chirurgie, 1881, pp. 220–229.

CHAPTER XV.

FRACTURES OF THE HYOID BONE.

This comparatively rare lesion has received the attention of writers only within the present century. Malgaigne collected 8 cases, Hamilton added 2, and Gibb 3; in 1864 Gurlt collected 27 cases, 21 being of the bone alone, while in 6 there was associated fracture of the thyroid or cricoid cartilage or of the trachea. In 3 of Malgaigne's cases and in 5 additional of Gurlt's the fracture was caused by hanging, judicial or suicidal, one of the latter surviving; in 6 of these one of the greater cornua was broken, in the remaining 2 the body. Gibb[1] says that Mackmurdo, a surgeon of Newgate prison for many years, found this fracture only four times on examination of the bodies of those who met their death there by hanging. In the other cases of the list the cause was violent grasping of the neck, or a blow, or fall, and in two cases apparently muscular action, general muscular contraction during a fall. Valsalva reports a case of "dislocation of one of the greater horns from the body," caused by the effort to swallow a large piece of food.

In the great majority of the cases the fracture was of one of the greater cornua, and usually at or near its junction with the body. In only three cases was the body of the bone broken, and in none the lesser horn.

The symptoms of fracture of one of the larger cornua, without accompanying injury of the larynx or trachea, are, according to the records, quite well-defined and characteristic; sharp pain at the seat of fracture increased by pressure, speaking, or swallowing; swelling in the same region appearing soon after the accident and due in part to extravasated blood; recognizable displacement or mobility of the fragment; crepitation; and sometimes free bleeding into the mouth, the result of perforation of the mucous membrane of the pharynx by the bone. Exploration of the pharynx will enable the surgeon to recognize displacement of the horn inward and perforation of the mucous membrane if they exist. The patient is seldom able to move the tongue freely or without pain, and in some cases attempts to depress it or put it out have caused paroxysms of suffocation. In all the cases it has been difficult or impossible to swallow, even a drop of water sometimes causing the patient to cough and choke, and in many of them it was necessary to give food through an œsophageal tube, in one case for twenty days. The patient finds it difficult to speak, and the voice is hoarse and low.

In the single case in which a fracture of the body of the hyoid bone was observed during life the symptoms were severe paroxysms of cough-

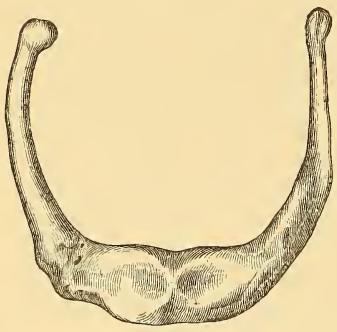
[1] On the Dis. and Injs. of the Hyoid Bone, London, 1862, p. 44; quoted by Gurlt.

ing, dyspnœa, lividity of the face, and abundant bloody sputa, and were relieved by the reduction of the displacement.

The local and general reaction after the injury has been quite marked, and although the bone appears to have united promptly convalescence has been delayed by the persistence of the dysphagia and of the change in the voice. In one case an abscess formed at the seat of fracture, and three months afterwards the necrosed posterior fragment was cast out.

The possibility of repair by a bony callus is shown by two specimens; one, taken from the body of an adult man without a history and presented to the London Pathological Society by Gibb, showing a fracture of the right greater horn which had united with overriding to the extent of one-quarter of an inch, and displacement inward; the other (fig. 154) in the pathological collection of the college at Brunswick, showing a fracture of the right greater horn united with some shortening and displacement downward.

Fig. 154.



United fracture of the hyoid bone. (Gurlt.)

The prognosis, so far as life is endangered by the injury to the bone, is favorable, but the associated injuries in the recorded cases have often been such as to cause death. Among these associated injuries fracture of the cartilages of the larynx is prominent.

The treatment requires the reduction of displacement, if possible; and this may sometimes be facilitated by the introduction of the finger into the pharynx. It is unlikely that a bandage would be of any service in opposing a tendency to the recurrence of displacement. The dysphagia may render nourishment through an œsophageal tube necessary, and the inflammation of the soft parts may require active local treatment.

CHAPTER XVI.

FRACTURES OF THE CARTILAGES OF THE LARYNX AND TRACHEA.

This injury, although actually rare, is more frequent and much more dangerous than fracture of the hyoid bone and has received more attention from writers. Gurlt's collection, published in 1864, contained 47 cases, Dr. Hunt[1] collected and analyzed 27 cases but did not give the details, and Henoque[2] collected 52 cases, to which Mr. Durham[3] added 10, making 62 in all, or including 4 of Gurlt's in which the trachea alone was injured 66.

The following table shows the relative frequency with which the different parts are affected:—

Cartilage broken.	Cases.	Deaths.	Recoveries.
Thyroid alone	24	18	6
Cricoid alone	11	11	
Thyroid and hyoid bone	4	2	2
Thyroid and cricoid	9	9	
" " " and hyoid bone	2	2	
" " " and trachea	2	2	
Cricoid and trachea	2	2	
" " " and hyoid bone	1	1	
"Larynx"	7	3	4
Trachea alone	4	3	1
	66	53	13

The causes are blows, falls, hanging, and the grasp of the hand in a fight, or in an attempt to strangle. The injury is seen more frequently in males than in females, and in middle life than at any other period, but youth and old age are not exempt. The mechanism of the fracture of the thyroid or cricoid is usually either lateral compression on both sides or pressure backwards against the vertebral column; the first causes commonly longitudinal fracture of the thyroid cartilage near its middle, together with flattening or depression of its sides, and either a double lateral fracture of the cricoid cartilage or a single fracture in the anterior median line; the second causes irregular and multiple lines of fracture. The mucous membrane of the larynx is frequently torn, and extravasations of blood take place under the skin and mucous membrane or among the muscles.

The symptoms of fracture of the larynx are frothy bloody expectoration with convulsive coughing and usually much dyspnœa and its attendant symptoms. The voice is affected or lost, and swallowing often

[1] Am. Journal Med. Sciences, April, 1866, p. 378.
[2] Gazette Hebdomadaire, Sept. 25th and Oct. 2d, 1868.
[3] Holmes's System of Surgery, Am. ed., vol. i. p. 697.

difficult and painful, although not so much so as after fracture of the hyoid bone; and in all severe cases, when there is laceration of the mucous membrane, emphysema appears promptly and spreads steadily over the neck, face, trunk, the extremities, and mediastinum, being sometimes more marked in the intermuscular than in the subcutaneous connective tissue and sometimes causing pneumothorax without wound of the lung.

The additional objective symptoms are deformity of the region and abnormal mobility of parts of the larynx upon each other, but both these signs may be unrecognizable on account of the swelling.

In some cases there have been no marked symptoms beyond a change in the voice, although the character of the injury was made clear by careful examination, and the difference seems to be due to the absence in these cases of any obstruction or narrowing of the air passages by displaced cartilages.

The course in the severe cases is towards prompt death by suffocation, either by gradual increase of the dyspnœa or by the sudden intercurrence of œdema of the glottis. Occasionally the dyspnœa does not make its appearance until some days after the injury. In the mild cases the symptoms gradually subside, and recovery follows.

It seems probable that repair is by a bony, or at least by a calcified, callus.

The treatment in the milder cases consists of local antiphlogistics and quiet; in the severer ones, of tracheotomy whenever the dyspnœa is great or increasing. It is not safe to wait until it has become extreme, for its increase at the last is often so rapid and sudden that death takes place before relief can be given. It is therefore the part of prudence to interfere early and before the interference is made actually necessary by the defective breathing. Advantage should be taken of the opportunity afforded by the operation to reduce any displacement that may exist and that can be overcome by manipulation through the wound.

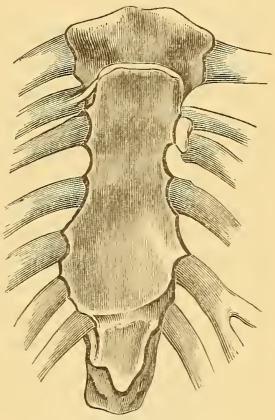
The symptoms of fracture of the trachea are similar to those of fracture of the larynx, except the local ones due to the displacements; the diagnosis is difficult because of the lack of symptoms distinctive of the seat and character of the lesion. The prognosis is unfavorable, and the treatment usually insufficient to avert the fatal termination or relieve the suffering, because in the few recorded cases the seat of injury has been beyond reach by operation. The indication for treatment is to insert a tube into the trachea past the point of fracture so as to insure free breathing.

CHAPTER XVII.

FRACTURES OF THE STERNUM.

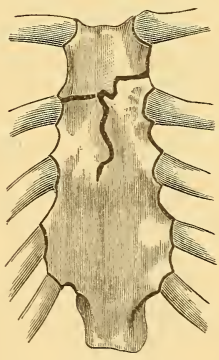
The sternum, formed originally of several pieces, has an irregular and uncertain development, only one feature of which, however, needs to be mentioned in this connection. The upper portion, the manubrium, usually unites by ossification with the central portion, the body, during the early period of adult life, but sometimes this union is delayed or actually given up, and in the latter case the connection between the two parts may be a real joint with cartilages of incrustation, a capsule, and synovia. A traumatic separation of these two portions under such conditions, is a dislocation or diastasis rather than a fracture, but as the distinction cannot always be recognized with certainty upon the patient, and as the symptoms and treatment are the same in either case, it seems advantageous to follow the general custom and describe all cases as fractures. The pathognomonic sign of a dislocation or diastasis, according to Malgaigne, is the recognizable outline of the articular border, usually the upper one of the second portion of the bone, which presents three facets, a central one for articulation with the manubrium, and one at each angle facing upward and outward for articulation with the second rib (fig. 155).

Fig. 155.



Diastasis of the sternum. (Malgaigne.)

Fig. 156.



Longitudinal fracture of the sternum.

The great rarity of the accident is clearly shown by statistics, only 22 cases appearing in the 22,616 fractures of all sorts treated during twenty years at the London Hospital (see table page 35), less than one-tenth of one per cent. It is unknown in childhood, the earliest recorded instances being one at the age of 15 years, one at 18 years, and a doubtful one at 14 years. As it is usually caused by great violence it has frequently been found associated with other fractures, especially with those of the ribs and vertebræ.

The fracture may be incomplete, multiple, transverse, oblique, or

longitudinal. Of the first form there are but two recorded instances; in both the infraction occupied the posterior surface of the bone at or near the junction of the lower and middle thirds, was transverse in one and oblique in the other, and in each was accompanied by an abundant extravasation of blood into the anterior mediastinum. One was caused probably by the kick of a horse, the patient being found dead upon the floor of a stable, the other by a fall upon the head from a height of about ten feet.

Of compound fractures, except such as were gunshot or stab wounds, there is but one example, reported by Duverney in 1751. A quarryman, while at work lying upon his side, was caught under a heavy stone about five feet long which compressed his chest laterally with such force as to separate the middle portion of the sternum from the upper portion and force it through the skin. Death was immediate, by rupture of the heart and lungs.

Of pure longitudinal fracture there is but one certain example, although there are two other cases in which there was a longitudinal fracture of the manubrium or of the body of the sternum associated in one of them with a transverse fracture at the junction of these two parts, and a third in which the diagnosis of longitudinal fracture, based upon the history of the case and the presence of a supposed callus, was made several years after the occurrence of the accident which was supposed to have caused the fracture. The first case was that of a man who was overthrown and crushed by a falling wall; in addition to numerous contusions, the sternum was broken longitudinally throughout its entire length, the right half being depressed from 8 to 10 lines below the level of the left half. There was profuse bloody expectoration and difficult breathing. Reduction was accomplished by drawing the right arm back and making forcible pressure upon the middle of the sternal ribs of the right side and gentle pressure upon the left side. The patient recovered in six weeks.

In the doubtful case the supposed fracture was caused by muscular action; the patient, a lad of 14 years, while quarrelling with comrades, retreated into a corner, fixed himself there by pressing with his hands upon the walls, and defended himself by kicking. While thus engaged, he felt a sudden slight pain in the breast, and found himself unable to continue the pressure with his hands. A few years later he studied medicine, his attention was directed to fractures of the sternum, and, recalling this incident of his youth, he suspected a fracture and had himself examined, in 1798, by several surgeons, who found what they supposed to be a callus occupying the centre of the bone along its entire length.

Cases of congenital fissure of the sternum have been reported as longitudinal fractures.

Simple transverse fractures form the great majority of fractures of the sternum, and occupy most frequently the junction between the manubrium and the body of the bone or its immediate neighborhood, that is, the region of the second intercostal space; next in frequency are fractures at or near the middle of the bone, corresponding to the third rib and the third intercostal space; they are rare in the manubrium and

below the middle of the bone, and very uncommon as separations of the ensiform appendix from the body.

Fractures of the manubrium occur, according to the few cases in which their position has been accurately described, most commonly a short distance, two or three lines, above the lower border of this portion of the bone; the periosteum sometimes remains untorn upon either the anterior or the posterior surface; in some cases there has been no displacement, in others either the upper or the lower fragment has been displaced forward, and in one case there was angular displacement, the apex of the angle being directed inward. In several of the cases the fracture was produced by muscular action, by straining during childbirth, or by the effort to raise a heavy weight with the teeth, the body being bent far back. In a large proportion of cases in which the lesion was produced by external violence, there was also fracture of the ribs, clavicle, or vertebræ.

Partial fractures have been observed in two instances, once in connection with fracture of the ribs, a scale of bone corresponding to the articulation with the first rib being broken off; a second time in connection with dislocation of the sternal end of the clavicle, the portion to which the sterno-cleido-mastoid was attached being torn off and drawn upward nearly half an inch; and in a third case in connection with a transverse fracture lower down.

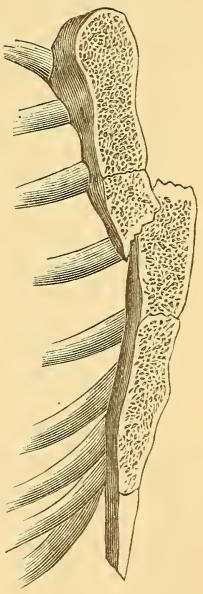
Transverse fracture at or near the junction of the manubrium and body of the bone, and diastasis at this point, which is not always to be distinguished from fracture, are the commonest forms of injury. In the great majority of cases the lower fragment is displaced so as to lie in front of the upper one, and sometimes to override; it is exceptional for displacement to be absent or for the upper fragment to lie in front of the lower one.

There is reason to think that the periosteum is almost invariably torn upon the anterior surface, but that it sometimes remains untorn behind, a fact which derives considerable importance from its bearing upon the escape of blood into the anterior mediastinum. One or both of the second pair of ribs usually remain attached to the manubrium.

Out of a total of 105 cases of fracture of the sternum collected by Gurlt, 27 are described as partial or complete diastasis at the junction of the first and second portions, the character of the lesion having been determined by post-mortem examination in fourteen of them.

Fractures of the body of the sternum (fig. 157) occur most frequently between the second and fourth costal cartilages, are usually transverse, but sometimes oblique laterally or from before backward. The displacements are the same as after fracture at the junction of the manubrium and sternum, and there is the same relative frequency of the

Fig. 157.



Transverse fracture of the body of the sternum.

projection of the lower fragment. Sometimes the fragments move quite freely upward and downward upon each other during the acts of respiration.

Comminuted fracture of the body of the sternum has been rarely seen except in connection with gunshot and punctured wounds. Of triple fractures Gurlt found only two cases, and of double fractures only six, all of them associated with fracture of other bones, usually the ribs or vertebræ.

Of fracture or diastasis of the ensiform appendix, Gurlt collected only four examples, and the list does not appear to have been increased by subsequent writers; one was a fracture, the other three diastases. The fracture was produced in a man sixty years old, by a fall upon the sharp edge of a grain measure, and, when last examined, nine months after the accident, was still ununited and crepitated on pressure, but caused no inconvenience. In the other three cases the prominent symptom was persistent vomiting, which in one lasted for two years, recurring every five or six days, and then ceased spontaneously; in another it was cured by grasping the process between two fingers, and bending it back into place; and in the third, after it had lasted a month, and death by exhaustion seemed imminent, it was instantly relieved by the reduction of the displacement, which was accomplished by inserting a blunt hook into the abdominal cavity through an incision, and drawing the process forward. The patients were aged respectively 28, 18, and 19 years.

The effusion of blood, which is observed after all fractures, may attain an especial importance after fracture of the sternum, by the pressure which it may exert upon the underlying heart. The blood, coming from the torn vessels of the bone and periosteum, makes its way forward into a region where it can do no harm, if the periosteum on the posterior surface remains untorn; but if this membrane shares in the injury, and especially if one of the internal mammary veins or arteries is ruptured, the blood makes its way into the anterior mediastinum, and sometimes in sufficient amount to cause death promptly.

Rupture of the pericardium, or of the heart, has been observed in a few cases; as has also probable laceration of the lung, evidenced by the appearance of subcutaneous emphysema or pneumothorax.

Etiology.—Fracture of the sternum may be produced either by muscular action or by external violence.

There are four recorded cases in which the bone has been broken by straining during labor, and three in which the fracture has occurred during an effort to lift a heavy object. An example of the former has been quoted in Chapter IV.; the following is an example of the latter.

A woman was trying to lift a heavy basket into a wagon, and, while standing with her head and shoulders thrown back and the basket resting against her belly, felt something crack in her chest with pain. A transverse fracture of the manubrium, two lines above its lower border, was recognized, with displacement forward of the lower fragment, abnormal mobility, and sharp pain on raising the chin, moving the arms, or coughing.

External violence acts either directly by a blow upon the breast, or

indirectly by forcibly bending the body forward or backward, or possibly by a combination of the two forms in the fall upon the body of a heavy object, or the passage across it of a loaded wagon. It is not necessary that the force which acts directly should be very great to produce fracture; it is sufficient for it to act upon a limited area, as in a fall upon a stone, or stick, or the edge or corner of a box.

The violence which produces indirect fracture is, in most cases, a fall either upon the shoulders or buttocks, or with the back or breast across some fixed object, so that the trunk is bent sharply forward or backward; in the one case the bone is broken by being bent forward, in the other by the traction exerted through the muscular attachments at either end.

The diagnosis is readily made by the objective symptoms, the displacement, mobility, and crepitation, by the localized area of pain excited by pressure, change of position, and the more violent respiratory acts. The position of the patient, too, is often characteristic, for the shortening of the sternum by the overriding of the fragments and the pain that is excited by traction upon the fragments lead him to keep a semi-recumbent or sitting position with the head and shoulders bent forward, and to carefully avoid any movement that tends to straighten the trunk. The examination of the bone must be made carefully in order, on the one hand, to avoid mistaking some irregularity of development for a traumatic displacement, and, on the other, not to overlook a second or third fracture, or even a single one in case there should be no displacement. The condition of the adjoining costal cartilages may be of much service in doubtful cases, such as diastasis at the junction of the first and second portions without displacement; thus, if the second costal cartilage on either side is found to project at its point of junction with the sternum, and especially if the projection can be reduced by pressure, the fact points strongly toward a diastasis. In cases of supposed injury to the ensiform appendix the frequent irregularities in the shape, position, and mobility of that part must be borne in mind.

The importance of the injury is by no means so great as the mortality of the recorded cases would indicate, for this mortality is largely due to associated lesions. Gurlt tabulated 98 cases with reference to this point, among others, and found that of 54 simple cases 46 recovered and 8 died, while of 44 complicated cases, cases, that is, in which there was some severe associated injury, only 1 recovered and 43 died. Of 20 cases in which the fracture was certainly caused by direct violence, 15 recovered, and 5 died, 3 of the latter being complicated cases. A mortality of 8 in 54 cases is high enough to prove the importance, the seriousness, of the injury, but so far as can be learned from an examination of the records it is not certain that the death was due to the fracture in all of them; thus, in the case quoted in Chapter IV., of fracture by straining during childbirth, and in another very similar one published by Chaussier, death was caused by peritonitis, and although an abscess was found at the seat of fracture it seems probable it was the consequence rather than the cause of the constitutional infection.

In the following case,[1] on the other hand, the injury itself was appa-

[1] Virchow, Gesammelte Adhandlungen, p. 579, quoted by Gurlt.

rently the sole cause of death. A man 25 years old was struck in the breast by the pole of a rapidly moving wagon; he lost consciousness at first, and complained after recovery of oppression and great pain in the chest. A chill occurred on the fifth day and was followed by several others; death on the eighth day. The autopsy showed a transverse fracture at the fourth intercostal space without rupture of the fibrous lining of the bone, extensive disorganization of the adjoining soft parts, especially the anterior mediastinum, purulent thrombosis of the right mammary vein, secondary pleurisy, pericarditis, and perihepatitis, with phlebitis at points where venesection has been made.

In another case reported by Duverney, in 1751, a comminuted fracture produced by moderate violence caused immediate death by laceration of the heart by the fragments. A young man playing skittles leaned forward after casting the ball to watch its effect and fell, striking his breast upon a stone and dying instantly. The body of the sternum was broken, the fragments pressed inward, the pericardium opened, and the right auricle torn in three or four places.

The course in the less severe cases is an uneventful one; in the only uncomplicated case which has come under my care, the patient, a man of 60 years, who had received his injury by the fall of a frame building, complained only of pain on pressure and on drawing a long breath, was able to lie upon his back from the first, and was soon dismissed cured, but with a slight projection of the upper end of the lower fragment. If pain and oppression are more marked at first they soon diminish and disappear, as do also the expectoration of blood, dyspnœa, and orthopnœa. In exceptional cases the local reaction may be great and may lead even to the formation of an abscess about the fracture. The pus may make its way to the surface between the fragments or on the sides, and if pulsation is communicated to it by the underlying vessels the surgeon may mistake it for a traumatic aneurism. If it collects upon the posterior surface and is discharged imperfectly through a small opening, the fistule may persist indefinitely, or the unnatural conditions may lead to extensive caries of the bone. Both conditions require treatment by active operative interference.

Usually repair takes place in from four to eight weeks, and by a bony callus. The persistence of a certain degree of displacement is not uncommon, and in some cases the deformity has been extreme. One is reported in which the bone had been driven in so far by the kick of a horse that it was almost in contact with the spinal column and left a depression in front in which the head of a six-year-old child could rest. The displacement had persisted for ten years, but the patient was perfectly well and there were no notable disturbances in respiration or circulation.

Failure of bony union has been observed in a few cases, but does not appear to have caused any disability beyond a temporary difficulty in abduction and adduction of the arms.

Gunshot fractures may be penetrating or non-penetrating. A number of illustrative cases of each kind are given in the Surgical History of the War of the Rebellion. The latter do not differ materially from com-

pound fractures due to any other cause, but in the former the prognosis is rendered very grave by the associated lesions.

Treatment.—The first indication is to reduce such displacement as may exist. This is not always possible; the most intelligently directed and persistently conducted efforts have sometimes failed. The usual method is direct pressure upon the projecting fragment, aided, especially when there is overriding, by traction upon the two pieces. The traction must be made, in part at least, through the muscles attached to the ends of the bone, and is accomplished sometimes by resting the back upon some rather firm object, as a cushion or box, and bending the head and shoulders forcibly backward. At the same time the patient may be directed to take a full inspiration, and the surgeon presses downward against the upper edge of the lower fragment if that one, as is usual, projects, or he draws this fragment downward by taking hold of the projecting ribs that are attached to it. Various modifications of the plan have been employed but all have the same fundamental idea, that of traction in opposite directions upon the fragments by forcible bending of the body backward.

A number of operative methods have been proposed for use in those cases in which the displacement cannot be reduced by manipulation, such as to raise the depressed fragment by a sort of gimlet screwed into it, or by an elevator or blunt hook passed under it through an incision, or to cut away the projecting portion with the knife or trephine, or to press it back with a rod carried directly down to it through an incision. Most of these remain as suggestions that have not been put to the test. One case has been already mentioned in which the ensiform appendix was drawn forward successfully by means of a blunt hook passed into the peritoneal cavity; in another, of fracture at the upper part of the sternum with depression of the lower fragment, an incision was made with the intention of introducing a hook, but the pleural cavity was opened and the surgeon felt it necessary to close the wound immediately. In another the upper fragment was raised to the proper level by screwing a sort of gimlet into it and drawing it forward, but it afterwards sank partly back again, and a second attempt to raise it was defeated by the tearing out of the screw. In a compound fracture caused by a blow with a bayonet the depressed fragments were raised with a spatula and one of them was entirely removed. The patient recovered after two narrow escapes from death by hemorrhage.

Unless the displacement is actually causing dangerous or distressing symptoms these methods of removing it by operation are not justifiable, because they carry with them risks that should not be lightly run. The pleural or abdominal cavity cannot be opened without danger of setting up a fatal inflammation, and the conversion of a simple fracture of the sternum into a compound one exposes to the chance of suppuration within the anterior mediastinum. On the other hand, the displacement usually involves no disability and no apparent or noticeable deformity.

The subsequent treatment consists in immobilization of the chest, and, if necessary, in the use of measures to allay local inflammation and to prevent coughing. A convenient dressing is a broad flannel bandage pinned tightly about the chest after forced expiration, or bands of adhe-

sive plaster extending from side to side across the front of the chest and covering the entire length of the sternum.

The trephine has been occasionally used to seek for and evacuate an abscess supposed to have formed behind the bone, but most authorities decline to recommend the measure, because of the uncertainty of the diagnosis, and advise that the surgeon should wait for the pus to make its appearance either between the fragments or on the side. Agnew[1] did the operation once and with a satisfactory result, but adds that he thinks it is better to wait. The justification for delay must be found in the difficulty of making the diagnosis, and as the risks attendant upon the operation when performed with antiseptic precautions are certainly less than those arising from a confined and growing abscess I should not hesitate to do an exploratory trephining if the symptoms indicated the presence of pus. The proper plan to pursue, in my judgment, would be to remove the disk of bone without division of the periosteum on the posterior surface, and then to seek for pus by puncturing in different directions with an aspirating needle.

[1] Surgery, vol. i. p. 860.

CHAPTER XVIII.

FRACTURES OF THE RIBS AND THEIR CARTILAGES.

These are among the commonest of all fractures, constituting according to different statisticians from ten to eighteen per cent. Thus, according to Malgaigne, of 2358 fractures at the Hotel Dieu 263 were of the ribs; of 2275 at Guy's Hospital[1] 222 were of the ribs; and of 51,938 at the London Hospital,[2] including "out-patients," 8261 were of the ribs, or about 16 per cent. According to Malgaigne fractures of the ribs are almost unknown in infancy and childhood, his statistics containing only three cases below the age of twenty years. Coulon[3] says that of 140 fractures in children observed by him at the Hôpital St. Eugenie during one year the ribs were broken only once, and that time by the passage of a heavily laden wagon across the chest; several ribs were broken, the fractures were incomplete and were recognized only at the autopsy. He refers also to a confirmatory statement by Marjolin to the effect that he had not seen more than two or three fractures of the ribs in 800 or 900 cases of fracture observed in children. I have myself observed one case in a child 9 years of age which was not recognized until after an abscess had formed and exposed the necrosed fragments; and taking that fact and Coulon's autopsy into consideration I am inclined to believe that fractures of the ribs in children may be more common than is supposed, but are overlooked because incomplete. They are much more common in men than in women.

Pathology.—Fractures of the ribs may be partial or complete, simple or compound, single or multiple. Partial fractures may be constituted either by a fissure involving only one of the borders of the rib and, perhaps, separating entirely a longer or shorter fragment of that border, or by an infraction. The former is uncommon; it was observed post-mortem in connection with complete fracture of other ribs by Lisfranc in a case quoted by Malgaigne, and was also produced experimentally by the latter. The fracture in Lisfranc's case is described as a longitudinal one running for one and a half or two inches along the lower border of the third rib; that in Malgaigne's circumscribed a fragment of the lower border of the fifth rib.

Infractions are similar to those seen in the long bones, that is, there is complete fracture on only one side of the rib; the periosteum is usually untorn. They constitute, as a rule, only a slight injury, and are therefore seldom seen post-mortem, except when associated with other fractures of the ribs, or with other injuries. A remarkable case of death

[1] Holmes's System of Surgery, Am. ed., vol. i. p. 747.
[2] See Table on p. 35.
[3] Traité des Fractures chez les Enfants, 1861, p. 87.

by hemorrhage after partial fracture of the eighth rib is quoted by Gurlt from the *London Medical Times and Gazette*, 1860, vol. ii. p. 607. The fracture was caused in a man, thirty years old, by a blow with a light cane, which left no mark upon the surface. Symptoms of collapse soon appeared, and death in seventeen hours. Five pints of blood were found in the right pleural cavity, and appeared to have come from a small rent in the pleura corresponding to a fracture of the inner surface of the eighth rib, about two inches from its anterior end. A small branch was found to leave the intercostal artery close to the rent and to pass toward it.

Complete fractures may be transverse, oblique, irregular, or multiple, and may be limited to a single rib, or may involve all the true ones on one side, and in some cases even many on both sides. The central ribs are the ones most frequently broken, while the first and the floating ribs almost always escape. The fracture may occupy any part of the rib; Malgaigne thinks it is more common in the anterior portion than elsewhere, and Hamilton says his own observation confirms this opinion. Agnew, on the contrary, says it does not accord with his experience of cases treated or specimens examined, most of which showed fracture in the posterior half. Malgaigne says he never knew a case of comminution except in gunshot fractures, and was never able to produce it experimentally.

The periosteum may remain untorn, and the fragments preserve their relations to each other, or they may form a re-entrant or a salient angle, or override each other by their sides or edges. If several ribs are broken completely or partially at the same time and forced inward, the depression may remain both broad and deep. Overriding of the fragments is impossible unless several ribs are broken at the same time, for the muscular and fibrous attachments of the adjoining ones hold the fragments in place, and the ribs above and below act as splints to prevent shortening. When several ribs are broken at the same time the side sinks in, and thus shortening and overriding are made possible. In at least five cases of double or multiple fracture of one or several ribs the intermediate piece or pieces have been so loosened that they moved in and out with every inspiration. Malgaigne quotes one of these cases as a very exceptional fact; Gurlt gives the details of five additional ones, two of which I reproduce briefly.

Middeldorpf saw a woman, sixty-three years old, with an extensive multiple fracture of the ribs on the right side, caused by a fall upon the edge of a tub; there was extensive emphysema of the right half of the body, and hemothorax. At each inspiration the side of the thorax was drawn in, and at each expiration it was forced out again. Recovery in fifty-four days.

Wutzer and C. O. Weber saw a man, fifty-six years old, over the right half of whose chest a heavy cart had passed from below upward, breaking all the ribs on that side except the first and the last, most of the fractures being double, and the intermediate fragment corresponding in length to the breadth of the wheel. The fragments of the fifth, sixth, seventh, and eighth ribs were entirely loose, and moved in and out with

a distinctly audible crepitation each time the patient breathed. The patient died on the third day.

In compound fractures the wound is rarely, if ever, caused by the projection of the broken end of the rib, but always by the object which produced the fracture.

The complications include injuries to the muscles, which are rarely important, to the intercostal arteries, and to the thoracic and abdominal viscera. The intercostal arteries appear to be very rarely injured; one instance has been mentioned already in which hemorrhage from a small branch of the artery followed incomplete fracture and caused death. Gurlt gives three additional ones, two of which terminated fatally; in the remaining one an aneurism formed which was cured in about six weeks by pressure, rest, and restricted diet. Laurent[1] quotes another of a man twenty-nine years old, who was standing with his breast resting against the edge of a bridge, when a friend sprang unexpectedly upon his back. It caused extreme pain in the breast, and an elastic pulsating tumor formed at the spot. Twelve days afterwards the breast was as large as that of a woman twenty years old; its border was hard, its pulsations plainly visible to the eye; it was not diminished by pressure, and gurgling was heard in it on auscultation. Fracture of the fourth rib was recognized. It was treated by repeated bleedings, with internal administration of ice, ergot, and digitalis. Two days afterwards the patient had a sudden attack of suffocation, with small pulse and nausea, and the tumor disappeared, leaving only the hard border; at the point of fracture was a gap, into which the index finger could be introduced, and where pulsation could be felt. The right arm had been paralyzed since the preceding day. The patient remained very ill for three days and then slowly convalesced. In March, 1868, Panas[2] mentioned, in the course of a discussion in the *Société de Chirurgie*, still another fatal case, which had come under his observation ten years before.

A wound of the pleura and of the lungs is a rather common complication, and is generally caused by the sharp end of a fragment, but in some cases fatal injury of the lung has been caused by the crushing effect of the external violence acting through the, perhaps unbroken, ribs; the thorax is compressed by the force, and the lung is put upon the stretch in such a manner that it is actually torn, not perforated by the bone. The case quoted from Coulon at the beginning of this chapter illustrates this point, the fractures were incomplete, but the lung was torn in two places, one rent being in the upper lobe, the other at the bottom of the fissure between the upper and middle lobes. Legros Clark[3] mentions two similar cases; in one the sixth, seventh, and eighth ribs were broken near their angles by a blow from the shaft of a wagon, and there was a large rent across the lung, but no perforation of it by the ribs; in the other, a child that had been run over, the lower lobe of the lung had been torn almost across, and, "although some ribs were broken,

[1] Des anévrysmes compliquant les Fractures. Thèse de Paris, 1874.
[2] Gaz. des Hôpitaux, 1868, p. 180.
[3] Diagnosis of Visceral Lesions, pp. 208 and 209.

the pleura was not wounded." The consequences of the wound vary with its size and with the relations existing between the lung and the thoracic wall. If these latter are normal, that is, if the lung is not adherent at the wounded part, air and blood escape more or less freely into the pleural cavity, and the lung collapses; if, on the other hand, the lung is adherent, the escaping air makes its way into the meshes of the connective tissue, and may spread through the mediastinum, under the pericardium and pleura, and into the interlobular tissue of the lung itself and the subcutaneous tissue on the surface of the body. Emphysema of the surface may be produced also when the lung is not adherent; the air which has escaped into and filled the pleural cavity is forced by the contraction of the chest during expiration out through the opening at the fracture, and its place is supplied at the next inspiration by fresh air drawn in through the wound of the lung, and thus a small quantity is pumped into the outer cellular tissue at each respiration, and this will continue until one or the other opening is closed by a clot or exudation or a change in the relations of its walls. The following cases will serve as illustrations:—

1. A man[1] received a violent blow in the side from the pole of a wagon; this was followed by coughing, slightly bloody expectoration, symptoms of suffocation, almost imperceptible pulse, and livid face. A circumscribed tumor appeared about an inch from the vertebral column, and became tense at each cough, with a sound like that of enclosed air. Emphysema spread over the breast and back, and was relieved by scarifications through which the air escaped with a hissing sound. The paroxysms of coughing became more frequent and violent, the dyspnœa increased, and death took place on the third day. The autopsy showed an oblique fracture of the "second and third last ribs" (eighth and ninth ?), two finger-breadths from their articulation with the spine; there was an opening as large as the end of the finger in the intercostal muscles and pleura, and a wound in the lung corresponding exactly to one of the broken ribs.

2. An old man[2] was thrown down and trodden under foot; several ribs were broken, and there was enormous emphysema of the body and neck with great dyspnœa, bloody expectoration, and small pulse. The autopsy showed a large quantity of air in the anterior and posterior mediastina and throughout the interlobular connective tissue of the lung; three ribs were broken on the right side, and there was a deep laceration of the right lung.

3. A man[3] was crushed between two railway wagons, and sustained fracture of five ribs—second to sixth—in front and behind, with extreme prolonged collapse and expectoration of blood and mucus. A tumor larger than an inflated sheep's-bladder appeared over the seat of the fracture, was distended at each respiration, and spread over more than half the body. Several punctures were made and a bandage applied; as the latter did not properly restrain the rising end of the second rib a spring

[1] Cheston, Pathological Inquiries and Observations.
[2] Dupuytren, Leçons Orales, 2d ed., vol. ii. p. 210. (Gurlt.)
[3] Provincial Med. and Surg. Journal, 1851, p. 488.

truss was added, and the fractured ends were thus kept in apposition. The patient expectorated a considerable quantity of pus streaked with blood, but made a complete recovery in six weeks.

Wounds of the heart are much rarer, and even more dangerous. Gurlt collected six cases, in only four of which the wound of the heart appears to have been caused by the broken rib; in the other two it appears to have been caused by the compression of the heart between the anterior chest-wall and the vertebral column, for the pericardium was untorn. The two following cases, from the *Dublin Journal of Medical Sciences*, 1837, vol. ii. p. 174, illustrate the two varieties:—

1. A brewer's man fell under a heavily laden dray, which passed over his chest. He was lifted up, complained of pain and weakness, but was able to sit on the side of the dray and drive the horse for nearly an hour, when, being in the neighborhood of a hospital, he thought he would get himself examined. He walked in and lay on a bed, but, on turning on his side, he suddenly expired. At the autopsy "it was found that the fifth rib was fractured, and that the extremity of one portion had penetrated the pericardium and right auricle of the heart; it filled up the perforation of the pericardium, but had freed itself from the heart." It was thought it had remained in the heart until the arrival at the hospital, and that the sudden death was caused by a change in its position that allowed the blood to escape into the pericardial sac.

2. A woman was crushed between a wall and a heavily laden cart and died almost instantly. Several ribs were broken and driven into the lungs. "The pericardium was distended with blood, the superior vena cava having been torn almost completely across from the right auricle."

There are also a few cases on record in which a broken rib has perforated the diaphragm, and even injured some of the abdominal viscera. Morgan presented to the Pathological Society of London the specimens obtained at the autopsy of a man who had died in consequence of a fall from a height of twenty-five feet. The sixth rib had perforated the pleura, the edge of the lung, the diaphragm, the ileum, and the spleen.

Etiology.—Fractures of the ribs may be caused by muscular action or by external violence. Violent coughing has caused fracture several times, sneezing once, turning in bed twice, an effort to avoid falling while walking once, and the exertion made in straightening a scythe blade once. Usually it is one of the lower ribs that is thus broken, but it has happened also to the fourth, fifth, and sixth. While some of the patients have been old and decrepit and their bones possibly more fragile than usual, others have been young and vigorous. Malgaigne[1] claims to have observed a sort of senile atrophy in the ribs affecting especially their thickness and making them much more liable to break; he says it is found also in connection with certain affections of the thoracic wall or viscera, and that he had seen it in a case of pulmonary emphysema and in one of cancer of the breast. In the latter case the tumor did not involve either the muscles or the ribs, yet the thickness of the latter was not more than one-third or one-fourth that of the ribs of the opposite side.

[1] Loc. cit., vol. i. p. 427.

By far the most common cause of fracture is external violence, by a blow, fall, or excessive pressure. The fracture may be direct or indirect, the former being perhaps more common in advanced life by reason of the less elasticity of the bone, but it is not often easy to distinguish between these two varieties. In double fractures one is often direct. It has been claimed on theoretical grounds that in indirect fractures caused by pressure upon or near the sternal ends of the ribs the bone would yield near its centre, at its point of greatest curvature; but this view is not supported by clinical or experimental facts. On the contrary, the fracture is found much more frequently in either the anterior or the posterior third, and indeed the point of greatest frequency seems to be very near that at which the force is received, an inch or two on the outer side of the sternal end of the bone.

Gurlt gives in connection with this two cases of fracture of the twelfth rib, one direct, the other indirect, and as they are thought to be the only instances on record I reproduce them here.

A girl 23 years old broke the twelfth rib on the left side by falling against the edge of a step. The fracture was two or three inches from the spine, there was much pain and crepitation. Recovery with notable displacement in four weeks.

Legouest[1] saw a case of indirect fracture of the left twelfth rib in a man 48 years old, caused by a fall against the edge of a table. The pain at first was severe; on the following day he was found in bed lying upon his right side with his head and shoulders well raised and breathing carefully and with short inspirations. Every movement caused pain; there was an ecchymosis over the anterior third of the rib at the point where the blow was received. By pressing upon the end of the rib distinct crepitation could be made out at the junction of the posterior and middle thirds.

Symptoms.—The symptoms of fracture of the rib in the less severe cases are likely to be obscure. There is often acute pain, catching respiration, and cough due, according to Legros Clark, probably to pressure upon, or injury to, the intercostal nerve, especially if the fracture is in the posterior portion of the rib. Pain is provoked by pressure, inspiration, coughing, sneezing, and certain movements of the body, but this may also be the result of a simple contusion without fracture. If, however, it can be determined that the pain is felt at a point more or less distant from that upon which the blow fell, the fact points strongly toward indirect fracture. The same may be said of ecchymosis; it may be due to contusion, but if found at a distance is a sign of fracture. Abnormal mobility is sometimes present, but the elasticity and mobility of the ribs make its recognition uncertain. It may sometimes be made out by placing a finger on each side of the suspected fracture, and pressing alternately with one and the other. The same manipulation may produce crepitation, but usually this is more readily recognized by placing the hand flat upon the chest, and pressing slightly at different points, or asking the patient to cough or draw a long breath. It may also be heard sometimes on auscultation of the chest, in the usual manner, and

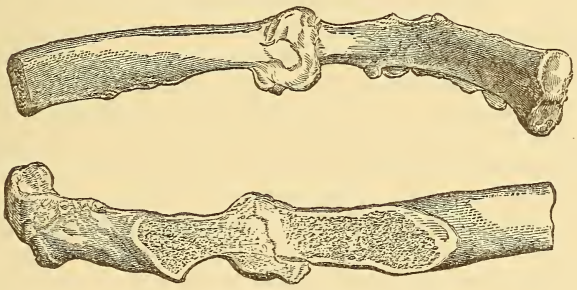
[1] Gazette des Hôpitaux, 1859, p. 65.

may be accompanied after a day or two by a pleuritic friction sound, the result of a pleurisy excited by the traumatism, and usually limited in area to its immediate neighborhood. The difficulty of detecting either crepitation or abnormal mobility is even greater at those points, where the ribs are covered by a thick muscular layer, or when there is inflammatory swelling, extravasation of blood, or emphysema. It is not uncommon for the patient himself to recognize the crepitation. Malgaigne saw a case in which, after fracture of the ninth rib, crepitation could be heard by those standing near the patient, whenever he made certain movements or drew a deep breath; and he refers to another in which the pulsations of the heart produced the same effect. Emphysema is, in itself, a very positive sign of injury to the lung and of fracture of a rib if there is no penetrating wound to account for it otherwise. Pneumothorax, or hemorrhage into the pleural cavity from a lacerated lung or an intercostal artery may be present in any of the severer cases; and bloody expectoration, which also points toward fracture, may be present in slight cases, and is not infrequently absent in grave ones.

The symptoms of partial fracture or infraction are seldom definite enough to permit a positive diagnosis.

The course of a simple uncomplicated fracture is usually quite uneventful; the patient remains quiet, sometimes keeping his bed, and breathes carefully and superficially to avoid pain; after three or four weeks he finds these precautions unnecessary, and the surgeon finds on

Fig. 158.



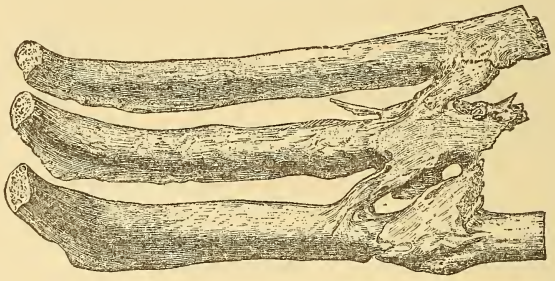
Fractured rib three months after the injury was received. (Holmes.)

examination that the local tenderness has disappeared, and that crepitation and mobility can no longer be detected. Union by a bony callus takes place almost invariably, notwithstanding the defective immobilization of the parts, but, as a consequence of the latter, the callus is likely to be large, and, when two or more ribs have been broken, to unite the adjoining ones by a bridge of new formation (fig. 159). Solidity is given at first by an ensheathing callus, and the union between the fractured surfaces, even when they are in apposition, may remain fibrous for several months. Failure of union is rare; Malgaigne had met with only instance and had heard of only one other. The latter was found upon a cadaver, and was a case of real pseudarthrosis with capsule and

synovial membrane. Paulet,[1] however, mentions four additional cases, and claims that it is by no means so uncommon as Malgaigne supposed.

Displacement upward or downward of one or more of the fragments may lead to its union with the adjoining rib, or to the formation of a lateral

Fig. 159.



Fracture of the ribs; exuberant callus. (Holmes's Syst.)

joint between them, as in the next following case, and in the specimen of the forearm represented in figure 73; or, if adjoining ribs are displaced in opposite directions, a gap may be left between them which may lead to hernia of the lung, as in the following case which is recorded in the *Gazette Médicale de Paris*, 1832, p. 465, and pictured in Cruveilhier's *Atlas d'Anatomie Pathologique*.

The patient died at the age of 62 years; in his youth he had sustained a fracture of the ribs by being crushed between the pole of a wagon and a wall. Between the third and fourth ribs on the right side near the sternum was a reducible tumor composed of normal lung and contained in a real hernial sac. The first rib was intact, the second and third were broken about three inches from their cartilages with displacement inward of the anterior fragment, overriding, and a vertical displacement that brought the posterior fragments into contact and led to the formation of a false joint between them. The fourth rib was bent sharply downward, forming the lower limit of a gap that was four inches long, and two and a half inches wide at the widest part, and that was bounded above by a small strip of bone extending from the fourth costal cartilage along the lower border of the third rib, and becoming attached to the latter near its middle.

A somewhat similar case is mentioned by Mr. Bryant[2] as having been under his care at Guy's Hospital in 1876. The sternal ends of the third and fourth ribs were broken and driven in without wound of the integument by a fall upon a wooden paling. "Hernia of the lung took place the size of a duck's egg, but an excellent recovery followed the reduction of the hernia and the peristent application of pressure." Still another case is described in the following section on fracture of the costal cartilages (p. 320).

It occasionally happens, as in the personal case mentioned in the note on

[1] Dict. Encyclopédique, art. Côtes, p. 70.
[2] Practice of Surgery, 3d Amer. ed., p. 575.

page 142, and in a few similar ones, that repair is interfered with by suppuration and by caries or necrosis of the broken rib, and does not become complete until after the removal of the diseased bone or the sequestrum.

The course and symptoms in the severer cases vary with the degree and character of the complications which give them their gravity. Emphysema may be slight and transitory, or it may continue for days and spread over a large portion of the surface of the body. If the air escapes into the cavity of the chest, or if the fracture is compound with a penetrating wound, the resultant dyspnœa and oppression may be extreme, and the physical signs of pneumothorax will be found upon examination. If, in addition to the escape of air, there is also free hemorrhage into the chest from the torn lung or an intercostal artery, the physical signs will be correspondingly modified. Extreme dyspnœa, due to congestion of the lung following promptly upon the injury, is not uncommon, and pneumonia occasionally results and leads to a fatal termination in the old and feeble.

Legros Clark[1] claims that serious functional derangement, without organic lesion of the lung, may result from contusion or concussion of the chest, that it may be transient or may be followed by inflammation, local or general, of the affected lung, and that it is sometimes observed in the lung on the side opposite that which has sustained the injury. He mentions illustrative cases of which I quote the following:—

A lad 12 years old was brought to the hospital after a fall from a height of forty or fifty feet which had caused no recognizable injury except a few bruises on the trunk and a portion of the humerus. The shock was moderate. The next day he had a flushed face and hurried and oppressed breathing; but, though the dyspnœa was urgent, there was neither lividity nor coldness of the lips or extremities. The heart's action was forcible and frequent, but the sounds were normal. Over the left side of the chest there was entire absence of resonance on percussion and of breath-sounds, and indeed of any sound but the heart's beat, except, perhaps, the feeblest murmur just below the clavicle. The vocal thrill was equally distinct on both sides. On the right side there was normal resonance on percussion, and the respiration was puerile. There was neither cough nor expectoration. Four leeches were applied over the upper part of the affected lung with almost immediate relief. On the following day the boy was breathing quietly; and in less than forty-eight hours all the symptoms had disappeared.

The prognosis depends largely upon the complications. Simple fractures without important complications do well as a rule; the exceptions are found mainly in the old and feeble whose lives may be endangered by congestion of the lungs, pneumonia, or pleurisy. Cases complicated by wound of the heart or pericardium are usually promptly fatal. Wounds of the lung are serious, but there are many instances of recovery even in cases where the laceration of the lung was probably extensive and accompanied a fracture that was in itself severe.

Mention may be made in this connection of the case of recovery after complete transfixion of the chest from side to side by the shaft of a

[1] Diagnosis of Visceral Lesions, p. 213.

chaise which measured five inches in circumference and penetrated for a length of twenty-one inches. The patient survived eleven years, and his thorax and the shaft are still preserved in the Museum of the Royal College of Surgeons, London.

Treatment.—The indications for treatment are to reduce any displacement that threatens to produce a complication, or that causes pain, to immobilize the chest-wall, and to relieve or prevent pulmonary inflammation or congestion.

Outward angular displacement may be corrected by pressure upon the projecting angle, and inward angular displacement may sometimes be corrected when the broken surfaces are still in contact, and the fracture is situated near the middle of the rib by pressing the sternum backward and thus springing the bone out. If the fragments have overridden this manœuvre is worse than useless, for it can only increase the displacement. Malgaigne says the method was proposed by Lionet for use in those cases in which the pain is severe although the displacement is slight. Malgaigne himself used it successfully to relieve pain, and found by experiment upon the cadaver that he could thus partially reduce incomplete fractures, but when he used much force the fracture was converted into a complete one. Relief may also be obtained by making the patient strain or draw full deep breaths. Ravaton relieved the pain and corrected the displacement in one case by suspending the patient upon two rods passed under his axillæ.

When the displacement was greater and one of the fragments was pressed inward Malgaigne ingeniously made use of the other to elevate it, pressing it in until the ends met and became locked together by the irregularities of their broken surfaces so that the elasticity of the second should serve to raise the first. He did this successfully in four cases and found that the pain was relieved by even a partial reduction, probably because that was sufficient to disengage some point of bone that had been driven into the flesh. He found it advantageous to have the patient strain while the effort was making.

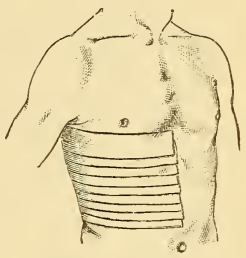
For this elevation or removal of a depressed fragment by operation a number of methods have been proposed, but very few instances are known of the use of any of them, Malgaigne referring to only three cases, and Gurlt to only one additional. Malgaigne's cases are those of Soranus and Rossi. Of the former he says that a wound of the pleura by the bone being suspected, he exposed the rib by an incision, passed a strip of metal under it to protect the pleura, and excised and removed the splinters. Rossi says he once removed a fragment of a rib, and on another occasion raised the posterior extremity (portion ?) of the ninth rib by means of a lever introduced through an incision made below it. The account of Gurlt's case is equally scanty, a young surgeon is said to have resected, in opposition to Stromeyer's express commands, a portion of the bone in a case of non-penetrating fracture of the seventh and eleventh (seventh to eleventh ?) ribs with an unfortunate result.

Malgaigne says that he never found it necessary to interfere in this manner, and that if the occasion arose he should prefer to use a hook like a tenaculum, passing it carefully behind the upper edge of the rib

and along its inner surface, and then raising the bone with it. Agnew says this is easily done upon the cadaver.

Immobilization of the chest is effected by surrounding it with a broad, snugly drawn bandage of muslin, flannel, or adhesive plaster. Some surgeons prefer to use strips of adhesive plaster two or three inches in breadth and only long enough to half encircle the chest, which they apply to the injured side letting each strip overlap one-third or one-fourth the breadth of the preceding one (fig. 160). Plaster of Paris has been used in a few instances, as have also sheets of felt or gutta percha moulded to the part and fastened on by straps of adhesive plaster.

Fig. 160.



Adhesive plaster strips applied for fracture of the ribs.

As the object of the bandage, whatever the material employed, is to immobilize the chest by suppressing thoracic respiration and making the diaphragm do the work it is essential that the abdomen should not be compressed, and therefore the bandage should be placed as high as possible, and, if necessary, prevented from slipping downward by bands passing over the shoulders. The guide to the amount of pressure exerted by it is the comfort or discomfort of the patient. If the pain is increased or the breathing interfered with, the bandage must be loosened or removed. As a matter of fact, the patient will himself immobilize his chest very satisfactorily by breathing carefully and superficially and by selecting and keeping a favorable posture if the movements of the chest are painful; the bandage, therefore, is seldom more than a comparatively unimportant aid. Malgaigne preferred a bandage three or four inches wide and long enough to pass once and a half around the chest, and he did not place it lower than the ensiform appendix, believing it to be sufficient, whichever ribs might be broken, to restrain the movements of the middle ones. When a circular bandage cannot be borne he recommends that a long narrow strip of plaster should be carried from the anterior end of the seventh rib on the right side, for example, across the front of the chest, under the left arm and across the back to and over the right shoulder, thence again across the chest in front, and around the left side and back to end at the crest of the right ilium. This immobilizes the left side of the chest very effectually and leaves the right side free. He suggests that in addition the arm should be fixed to the side.

The pressure of a bandage is useful also to prevent the spread of emphysema. This complication seldom requires any more active treatment, although scarifications are not infrequently made or the air drawn off through a trocar. If either method is used the instrument must be applied at a distance from the fracture, so as not to incur the risk of making it a compound one. The more dangerous variety of emphysema, that in which the air makes its way into the mediastinum and the interlobular tissue of the lung, is not amenable to operative treatment.

In pneumothorax it may be desirable to draw off the air through an aspirating needle or a canula in order to relieve the pressure, and if blood accumulates within the pleural cavity in quantities sufficiently large

to endanger life by interference with the action of the heart and either or both lungs it may become necessary to remove it by aspiration or incision, but the indications should be very plain before the surgeon decides to interfere in this manner, since the removal of the clotted blood and the relief of pressure may only lead to a return of the bleeding. Persistent internal hemorrhage can be treated only by indirect measures, because its source cannot be recognized, and if recognized, probably could not be reached. It has been found useful to constrict the thighs circularly at the groin with rubber tubing or a roller bandage just sufficiently to arrest the venous current; this withdraws a considerable amount of blood temporarily from circulation and acts as a venesection. It sometimes arrests bleeding instantly.

When life is threatened by pulmonary engorgement with extreme dyspnœa, blood should be taken from the arm immediately and freely, and the bleeding should be repeated if the symptoms reappear. The older records are full of cases showing the benefit of this practice, and among modern surgeons, Mr. Bryant recommends it unhesitatingly and forcibly. He says: "Bleed with no sparing hand. . . . When relief has been obtained arrest the flow immediately, as syncope can only do harm," and he supports the advice by the history of the following case.[1]

"In a case of severe injury to the chest, caused by the passage over it of the wheels of a heavily laden cart, that came under my care some time ago, fracture of five or six ribs and dislocation of the clavicle occurred, associated with collapse, intense dyspnœa, and hæmoptysis; I bled the patient twice in twelve hours, and each time with immediate relief, the case going on to good recovery. In it the severe dyspnœa and venous congestion, the rapid and hard pulse that came on as soon as the collapse of the accident had passed away and the circulation had been restored, too surely pointed to an excessive engorgement of the lungs, and so if relief were not afforded, absolute suffocation would speedily ensue by the patient's own highly carbonized blood. At such a crisis, antimony, however beneficial in simpler cases, could not be trusted, as there was no time for it to take effect. Under these circumstances bleeding was performed, and, as the blood flowed, life seemed gradually to return; the laborious breathing became quiet and subdued; the deadened and congested eye bright and natural; the pulse from being full and hard, softer and less bounding; and the boy's feelings, released from the impression that death was nigh at hand, became more hopeful and resigned; and, as a spectator, I felt such a hope was valid, and that success might crown our efforts. After the lapse of twelve hours, however, the symptoms returned, and the repetition of the bleeding was followed by a repetition of all its benefits. The antimony then came in to complete the cure; by the double venesection the pulmonary vessels had been relieved of their congestion, while the antimony, in acting upon the circulation, perfected the cure by preventing a return of the former threatening symptoms. The benefits arising from the treatment adopted in this case have such a lasting hold on my memory that I cannot too

[1] Practice of Surgery, 3d Am. ed., p. 573.

strongly recommend the practice thus pursued, and the more so, as I have seen it equally successful in other cases."

Fracture of the Costal Cartilages.

The first mention made of this lesion appears to have been by Zwinger in 1698, and it is not again referred to in medical literature until 1805, when Lobstein, at Strasbourg, and in 1806, Magendie, at Paris, each described it with cases. Additional observations were made by Delpech, Sir Astley Cooper, and Velpeau, and in 1841 Malgaigne[1] published a paper upon the subject which, six years afterwards, he reproduced in part, in his book on fractures. Since then but little work has been done upon the subject, most writers contenting themselves with reproducing in substance Malgaigne's chapter. Gurlt collected more than thirty cases for the chapter upon it in his book on fractures, and Paulet,[2] who appears not to have known of Gurlt's work, gives fourteen cases which he obtained by a partial search through French periodical literature, only four of which are mentioned by Gurlt. The known instances of this lesion unaccompanied by other fractures are few in number, but still throw sufficient light upon the more important and practical questions that arise in connection with it.

Fracture occurs much more frequently at or near the junction of the cartilage and rib than at any other point, and more frequently in the seventh and eighth ribs than in any other. The fracture may be double, and may involve several cartilages on one side or on both. Paulet gives two instances of double fracture, both healed and without history, having been found in the dissecting room. As one of them is also the only known example of incomplete fracture, I reproduce the description. The observation is attributed to Duguet, but the reference is not given. "The eighth and ninth ribs on the left side are the seat of a double solution of continuity, the rupture following two parallel vertical lines. The first line on the eighth rib is three centimetres from the costo-chondral junction, and five centimetres on the ninth. The second is three centimetres from the first. Both fractures are complete upon the eighth cartilage, but only the outer one on the ninth."

All the recorded fractures have been complete with the exception of this one case; they have been perpendicular to the long axis of the cartilage, or very slightly oblique, and the surface has always been smooth, without serrations or splinters.

It is probable that persons advanced in life are more liable to this fracture than the young, because of the calcification or ossification of the cartilages, but it has occurred in young men (17 years) and even in a child 7 years old.

Displacement has been absent in a very few cases; in most it takes place in the antero-posterior direction, and, in some, the fragments have overridden in the direction of the long axis of the rib. This latter form, probably, is possible only in the longer and more curved ribs, or when

[1] Bulletins de Thérapeutique, 1841, p. 227.
[2] Dict. Encyclopédique, 1st Series, vol. xxi., art. Côtes, 1878.

several adjoining ones are broken. The separation in either of these two directions may amount to as much as an inch, but is rarely so great. Either fragment may lie in front of the other, although the costal fragment projects more frequently than the sternal one; the displacement, however, appears to depend entirely upon the direction of the fracturing force and upon the position occupied by the patient, and consequently to follow no definite laws.

No instance of a compound fracture of a costal cartilage is on record, and the complications are less frequent and, as a rule, less serious than those accompanying fractures of the ribs. In some cases where the violence has been extreme and many cartilages have been broken fatal injury has been done at the same time to the heart or great vessels, but not by the penetration of one of the fragments; the viscera are crushed or torn by the continued action of the force after the wall of the chest has yielded under it. In a case reported by MacLeod a bullet struck the front of a soldier's cuirass and bent it in, breaking the cartilages of the fifth, sixth, and seventh ribs close to the sternum. The man went to the rear, walked about for two hours, was then taken with violent pain in the region of the heart, and died three days afterwards. The left ventricle was found ruptured.

Hernia of the lung has been observed in three cases, one after fracture of the third and fourth cartilages and rupture of the intercostal muscles by the fall of a heavy weight, the second, a double one, after fracture or diastasis due to paroxysms of coughing, and the third, observed by Legros Clark[1] after a blow received from the shaft of some vehicle. In this one the cartilage of the second rib was driven in, creating a gap through which a tumor as large as the first appeared at each inspiration and disappeared at each expiration, leaving a depression capable of containing at least two ounces of liquid. Recovery in three weeks, the gap persisting but "evidently occupied by some plastic deposit."

In seven cases the fracture has been produced by muscular action, either an excessive effort, as to avoid a fall or to throw a heavy object, or coughing or sneezing. Thus Broca[2] reported the case of a porter at the market who having placed a sack of peas upon his shoulder asked a comrade to add another to it. The latter threw the second sack heavily upon him, and in the effort to avoid a fall under the weight he fractured the cartilages of the sixth, seventh, and eighth ribs on the right side at points seven or eight centimetres from the median line.

Fractures by external violence may be direct or indirect; in many cases it is difficult, sometimes impossible, to recognize the mechanism. Gurlt thinks the indirect fractures take place at or near the costo-chondral junction, the force acting upon the rib itself in such manner as to spring its anterior end outwards, while in the direct fractures the force is exerted upon a restricted area of the cartilage itself, as in a fall upon the edge of a tub or step, the blow of a fist, the kick of a horse. The following cases will serve as illustrations.

[1] Loc. cit., p. 206.
[2] Quoted by Paulet, loc. cit., p. 83.

1. A man 46 years old[1] was caught in a mill and crushed between the beam and the wall. The ends of all the ribs on both sides projected distinctly at their junction with the cartilages, and "his chest was to the feeling like a dead body where the thorax had been opened and the sternum left loose under the integuments. The outer end of the left clavicle was dislocated. The patient was pale, breathless, and covered with cold perspiration." Venesection, bandage about the chest, shoulders retracted by a figure-of-eight bandage. Complete recovery in twenty-five days, the ribs still projecting on the right side.

2. A mason fell sixty feet[2] and died in a few hours. Besides an injury to the head and fracture of the ribs there was found a considerable depression of the anterior lower part of the breast on the right side due to fracture of the cartilages of the sixth, seventh, and eighth ribs with overriding of the fragments for about an inch, which could not be corrected even at the autopsy.

3. A man was thrown from and stepped on by his horse,[3] the hoof resting on the upper and anterior portion of the chest. There was some dyspnœa, local pain, but no ecchymosis. The fourth cartilage was forced backward and downward, the anterior end of the corresponding rib projected. At each deep inspiration the cartilage returned to its place, but the displacement recurred during expiration.

The symptoms are local pain and deformity. Crepitation and abnormal mobility are not often recognizable, but if displacement is present it can usually be made out by following the outline of the rib and cartilage with the finger and by observing that it can be increased or diminished by pressure upon one or the other fragment. It may be easy in some cases to say whether the fracture involves the rib or the cartilage, and in others whether it is a fracture of the cartilage or a dislocation of its sternal end, but the question has no practical importance. In the first case examination of the projecting end of the posterior (vertebral) fragment with an acupuncture needle may show whether it is composed of bone or cartilage; and in the second the outline of the sternum will show a small projection if there is a fracture close to it, and a cup-like depression if the injury is a dislocation.

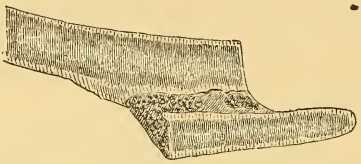
The prognosis, independent of complications, is favorable, and the fracture may be expected to unite in three or four weeks. Our knowledge of the mode of repair has been obtained partly by experimentation and partly by examination of specimens. When the fragments remain end to end and the fractured surfaces are more or less completely in contact, a fibrous band unites them, and the union is strengthened by an external ring of spongy bone. In a specimen obtained by Basserau[4] and examined microscopically by Malassez it was found that the central band was partly cartilaginous, and it is asserted that in other specimens points of ossification have been found.

When the fragments override, they take, so far at least as the broken ends are concerned, little or no part in the repair. Union is accom-

[1] Chas. Bell, Surgical Observation, London, 1817, p. 171.
[2] Magendie. Bibliothèque Médicale, 1806, p. 82. (Gurlt.)
[3] Bouisson. Quoted by Gurlt.
[4] Paulet, loc. cit., p. 88.

plished by an intermediate band which is at first fibrous and afterwards becomes bony (fig. 161); or if the fragments are in contact, the new bone forms on the sides and the ends (fig. 162), and in both cases it

Fig. 161.



Repair of fracture of a costal cartilage. (Gurlt.)

Fig. 162.

Repair of fracture of a costal cartilage.

envelops the pieces more or less completely like a ring. This ring originates apparently in the perichondrium, and its ossification is the final result of the formative irritation created by the traumatism, and is analogous to the ossification seen so constantly not only in cartilage which would normally be transformed into bone, but also in others, such as that of the larynx, whose normal evolution does not include that change.

The treatment is similar to that of fracture of the ribs; reduction of displacement if necessary and possible, and immobilization. The former must be accomplished, if at all, by pressure, by placing the patient upon the opposite side or upon his back, by drawing the shoulders back, or by deep inspirations; the latter by a body bandage, strips of adhesive plaster, or, following Malgaigne's example, by a hernial truss so placed as to restrain the fragment that tends to project.

CHAPTER XIX.

FRACTURES OF THE CLAVICLE.

THE clavicle is more frequently broken than any other bone in the body, the radius perhaps excepted, as a reference to the tables of statistics in Chapter I. will indicate, and as the following table compiled from a similar source as the others and with more detail will prove. Statistics composed only of cases treated in hospital give a frequency that is relatively much less, because many of the cases are treated as "out-patients." Thus the statistics of the Paris hospitals for four years, 1861–64, contained 7687 fractures, of which those of the leg formed 15 per cent., of the ribs 13 per cent., of the radius 9.8 per cent., and of the clavicle 7.9 per cent.[1]

Fractures of the Bones of the Upper Extremity treated at the Middlesex Hospital during a period of Sixteen Years ending June 30, 1867.[2]

	Age.												Total.		
	0 to 5.		5 to 15.		15 to 30.		30 to 45.		45 to 60.		Above 60				
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M. F.
Scapula	5	3	3	...	1	1	11	6	7	...	1	1	28	11	39
Clavicle	176	171	84	47	56	26	67	33	51	33	18	10	452	320	772
Humerus — Upper end	1	4	7	2	5	...	11	5	8	4	5	8	37	23	60
Humerus — Shaft	39	22	42	17	27	18	25	16	11	16	6	15	150	104	254
Humerus — Lower end	8	4	46	3	14	2	2	2	5	1	1	1	76	13	89
Olecranon	1	...	7	2	23	3	14	5	8	4	4	5	57	19	76
Ulna exclud. olecran.	8	7	19	1	7	6	19	10	13	10	2	5	68	39	107
Radius alone	62	64	92	19	78	45	75	57	45	123	21	87	373	395	768
Ulna and radius	20	17	71	11	15	7	8	9	9	12	4	8	127	64	191
Carpal bones	...	...	...	...	...	...	...	...	...	...	...	...	1	....	1
Metacarpal bones	1	1	10	1	62	9	50	13	15	3	3	...	141	27	168
Phalanges	3	2	44	7	47	8	32	13	24	5	4	1	144	36	180
Total	324	295	425	110	335	125	315	169	196	211	69	141	1654	1051	2705

It also shows that in nearly half the cases the patients were not more than five years old, that up to this age the frequency is about the same in the two sexes, and that afterwards the injury is more common in males than in females. Gurlt's Berlin statistics make the frequency after the age of ten years nine times as great in males as in females, but his statistics include only 113 cases. There are nine or ten recorded cases of intra-uterine fracture by external violence.

[1] Dict. Encyclopédique, art. Clavicle, p. 677.
[2] Holmes's System of Surgery, Am. ed., vol. i. p. 845.

Pathology.—It has been found convenient by most modern authors for the purposes of study and description to divide the fractures into three groups, according as they occupy the inner, middle, or outer thirds of the bone. The average length of the clavicle is six inches, and this division into thirds of about two inches each corresponds to anatomical differences of considerable clinical importance. To the flattened outer third are attached the trapezius and deltoid muscles and the strong coraco-clavicular ligament binding it to the coracoid process, the inner fasciculus of which, known as the coracoid ligament, marks the inner limit of this portion, and can sometimes be readily felt upon the living body. The dividing line between the inner and middle thirds is not so definitely marked anatomically, it corresponds approximately to the point where the clavicle crosses the lower or outer edge of the first rib. The inner third is attached to the sternum by the sterno-clavicular ligaments; and to the cartilage of the first rib by the costo-clavicular or rhomboid ligament. To its upper border is attached the sterno-cleido-mastoid muscle, to its lower the pectoralis major.

Since the outer third is broadly attached by ligaments to the scapula it is apparent that after fracture of the bone in the inner or middle third the outer fragment will not be able to change its relations to the scapula materially, and that its displacement therefore will be governed by the change of position of the latter, by its sinking inward and forward to the side of the chest in consequence of the loss of its anterior support.

The outer portion of the middle third is by far the most common seat of fracture, apparently because this is the smallest and most sharply curved part of the bone and must therefore yield to indirect violence more readily than any other part. Hamilton[1] says that of 157 cases, exclusive of gunshot fractures, 127 were in the middle third; and excluding the partial fractures, the fracture was nearly always near the outer end of this third; 4 were in the inner third, 17 in the outer third. He adds, further, that he has seen only one case of complete fracture in the adult produced clearly by a counter stroke that was not near the outer end of the middle third. Of 140 cases treated in the New York Hospital,[2] 3 were near the sternal end, 4 at the junction of the inner and middle thirds, 43 in the middle third, 67 at the junction of the middle and outer thirds, and 23 near the acromial end. Of 61 cases observed by Hurel,[3] exclusive of double fractures, 44 were of the middle third, 14 of the outer third, and only 3 of the inner third; three-fourths of those of the middle third were situated at or within half an inch of its outer end.

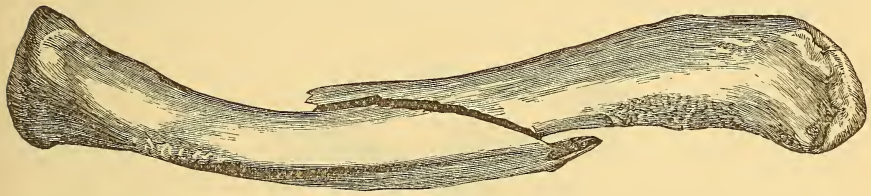
The fracture, like others, may be partial or complete, single or multiple, simple or compound; the most frequent form is simple complete fracture. Compound fracture is so rare that Gurlt says he could find only four examples of it, and Hamilton, who gives the same four cases, says he had never met with an example. A case has recently been under my care at Bellevue Hospital (1881); an Italian laborer was struck by a falling stone upon the shoulder and sustained a fracture of the right clavicle at a point nearly two inches from the sternal end of

[1] Fractures and Dislocations, 6th ed., p. 195.
[2] Lente, N. Y. Journal of Med., 1851, vol. ii. p. 159.
[2] Les Fractures de la Clavicule, Thèse de Paris, 1867, p. 48.

the bone. The line of fracture was oblique from above downward and inward. A large ragged wound extended backward across the clavicle and shoulder, in which some of the divided fibres of the trapezius could be seen. The outer end of the inner fragment was directed sharply upward, the outer fragment lying below and a little distance from it. The wound healed almost entirely in about six weeks, but when last seen there was still a sinus over the end of the inner fragment from which pus flowed freely and through which a probe could be passed to the bone.

Incomplete or partial fracture is, according to Hamilton, who has given much attention to this variety, very common. He thinks that 34 of the 157 fractures of the clavicle recorded by him[1] were partial fractures, and says that at least eleven of these were immediately and spontaneously restored to their natural axes. The symptoms accepted for this diagnosis are the history of a fall upon the shoulder, or at least indirect violence, the youth of the patient, a swelling upon the upper surface and front or rear border of the middle third of the bone appearing within two or three days after the accident, possibly a change in the axis of the bone, and possibly ability to straighten it with slight crepitus.

Fig. 163.



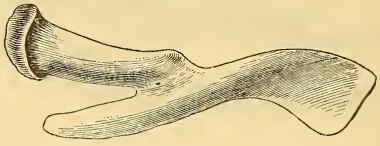
Oblique fracture of the clavicle.

1. *Complete Fractures of the Middle Third* may be oblique or transverse, the former variety being found most commonly in adults, the latter in children. The line of an oblique fracture usually runs inward and downward or backward, but may take any other direction and may be nearly transverse, or extremely oblique (fig. 163), or practically longitudinal as in a case observed by Chassaignac and mentioned by Polaillon[2] in which the fracture ran from the centre of the acromial end to a point just external to the sterno-clavicular articulation, dividing the bone into two longitudinal halves. Transverse fractures are thought to always present an irregular or toothed surface, a condition opposing displacement; and in consequence of this fact and of the other that this variety is more commonly found in children, it often happens that the periosteum is not torn. Multiple and comminuted fractures are rare. Hamilton has seen only six cases of the latter, exclusive of gunshot fractures, all occupying the middle third. I have seen one such, also of the middle third, with much displacement of the fragments and threatening of perforation by the sharp end of one of them, which was, however, prevented. When the fracture is multiple or double, the intermediate fragment is likely to occupy a very irregular position.

[1] Fractures and Dislocations, 6th ed., p. 90.
[2] Dict. Encyclopédique, Art. Clavicle, p. 682.

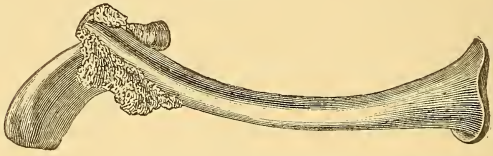
The displacements which are the most common are produced by the falling forward, downward, and inward of the shoulder, the consequence of the loss of the support normally furnished by the clavicle, and depend somewhat upon the direction of the line of fracture. The commonest form is that in which the sternal fragment is drawn upward by the sterno-cleido-mastoid muscle or pushed upward by the other fragment which is displaced inward along the under or anterior surface of the other and has at the same time changed its direction somewhat by the sinking of its acromial end. The shortening may be very notable, nearly one-third of the entire length of the bone in a specimen mentioned by Malgaigne. Another form is found where the line of fracture is such that the fragments do not readily leave each other, and the broken ends are displaced together upward and backward by the falling in of the shoulder so that the bone forms an angle at the seat of fracture. In some exceptional cases the outer fragment has lain upon the upper or posterior surface of the inner fragment. Malgaigne[1] says this variety was mentioned by Hippocrates, and that he himself saw one, but only one, example of it. Under these circumstances the sternal fragment is held down instead of being pushed up by the other one, and the displacement is mainly in the direction of the latter, the inner end of which is turned upward forming a projection at the seat of fracture. Figs. 164 and 165 represent ex-

Fig. 164.



Fracture of the clavicle. Union with extreme displacement.

Fig. 165.



Fracture of the clavicle.

treme angular displacement after fracture, in one case in the outer third, and in the other near the inner limit of the middle third.

In transverse fractures the broken surfaces seldom leave each other, and the only displacements possible are in thickness and direction, the lateral and angular. The lateral is the one usually seen, the angle being directed, for reasons that have been already stated, upward and backward.

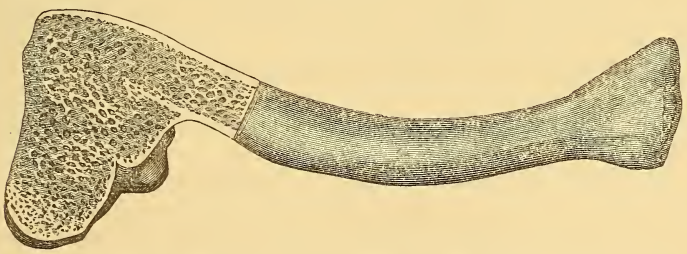
The most common and persistent cause of these displacements is undoubtedly the tendency of the scapula and shoulder to fall forward and inward upon the chest, but it is aided largely in the first place by the

[1] Loc. cit., p. 468.

fracturing force which continues to act after the bone has yielded to it. Thus, in a fall upon the shoulder or the outstretched hand, the clavicle breaks by the exaggeration of its normal curves, and as the direction of the line of fracture is usually downward and inward the outer fragment is forced inward on the under side of the other and necessarily turns the outer end of the latter upward. In like manner, if the fracture is by direct violence acting downward and backward the force, continuing to act after the bone has broken, depresses the broken ends in the same direction.

2. *Fractures of the Outer Third.*—This variety is next in frequency to the preceding, and may be produced by direct or indirect violence. The direction of the line of fracture is more commonly transverse than oblique. The degree of displacement varies greatly in different cases, being very notable in some and slight or entirely absent in others. R. W. Smith, of Dublin, attributed these differences to the position of the fracture, according as it lies within the area of the attachment of the coraco-clavicular ligament, or on the outer side of it, and he maintained that displacement was slight or absent in the former case, because the fragments were retained in contact by the untorn ligament that was attached to both, and might be great in the latter, because then the outer fragment was uncontrolled by fixed bands. Gordon[1] called in question the accuracy of both the explanation and the statements, claiming not only that displacement might be very marked when the fracture lay within the region of the ligament, but even that the majority of the fractures lay within this portion. Gurlt accepts Gordon's views, so far at least as to admit that displacement may, or may not be present, and supports them by reference to specimens. He further criticizes Smith's estimate of the distance to which the attachment of the ligament extends outwardly, and gives it a much wider range, one that includes all but about the outer inch of this division of the bone. This anatomical fact

Fig. 166.



Fracture of clavicle, outer third. Extreme angular displacement. (R. W. Smith.)

makes one of Smith's own specimens support the statements of his critics (fig. 166). When displacement exists it is usually an angular one, the apex of the angle being directed backward. In some specimens[2] bony

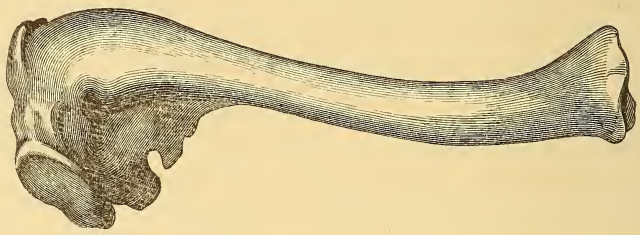
[1] Dublin Journal Med. Sci., 1859, vol. ii. p. 478.

[2] Smith, in Dublin Journal Med. Sci., 1842, p. 478, and Fractures in the Vicinity of Joints, p. 212.

union is shown to have taken place between the clavicle and the scapula, presumably by ossification of the coraco-clavicular ligament. It is in the form of a prop extending from the under side of the clavicle to the base of the coracoid process, and sometimes to the notch of the scapula, and usually convex posteriorly.

When the fracture is external to the trapezoid ligament, that is, when it lies within the outer inch of the bone, displacement is the rule, the outer fragment turning forward and inward until its axis is at right angles with that of the inner fragment (fig. 167); sometimes its broken

Fig. 167.



Fracture of clavicle, outer third. Union with displacement of outer fragment. (R. W. Smith.)

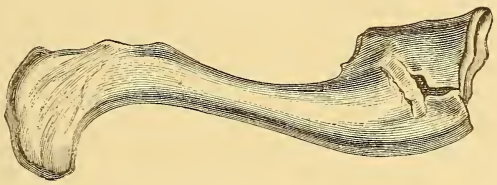
surface lies against the anterior border of the inner one, and sometimes the outer fragment lies under the inner one. Malgaigne describes a case in which, after fracture within half an inch of the articular surface, the inner fragment was elevated an inch above the other, and there was shortening of nearly half an inch; the appearance, in short, was that of a dislocation upward of the acromial end of the clavicle. An instance of extreme deformity after fracture at three-fourths of an inch from the acromial end is described and pictured by Smith. "The supra-clavicular space was diminished in a remarkable manner by the elevation of the clavicle which formed a very acute angle with the posterior border of the sterno-mastoid muscle. The shoulder was drawn forwards and inwards, the distance between the sterno-clavicular articulation and the extremity of the acromion being nearly an inch less than upon the opposite side." The outer end of the clavicle is raised high above the acromion. The relations of the fragments to each other are shown in figure 167.

3. *Fractures of the Inner Third.*—The older division, which was into fractures of the body and fractures of the outer end, took no special notice of this variety which received its first separate description from Malgaigne. It is the least common of the three; Delens[1] who wrote the first formal article upon the subject collected 28 cases, to which Polaillon, two years later, added 3. The fracture may occupy any point in the division, and is more often oblique than transverse. It was asserted at first that displacement did not occur if the fracture was within the region of the attachment of the costo-clavicular ligament, but the contrary has since been proved; displacement may take place in any

[1] Archives Générales de Méd., 1873, vol. i. p. 529.

direction, but the commonest one is downward and forward of the inner end of the outer fragment, or of the adjoining ends of both fragments if they do not separate from each other. Polaillon attributes the principal part in the production of this displacement to the action of the pectoral and deltoid muscles upon the outer fragment, and finds support for his opinion in the fact that this displacement has always been observed after fracture by muscular action; and as in this variety the fracture is usually near the inner articular surface, in a region, that is, where displacement after fracture by other causes is slight or absent, the argument is not without weight although the obliquity of the line of fracture in such cases as that represented in figure 168 cannot be entirely foreign

Fig. 168.



Fracture of the clavicle, inner third. (Gurlt.)

to the direction and degree of the displacement. When the fracture is transverse the lateral displacement may be slight or entirely absent and the periosteum may remain untorn. Longitudinal fracture with comminution was seen in one case, and Hamilton reports another in which the line ran from the articulation upward and outward for one and a half inches. The fragments overlapped three fourths of an inch and were firmly united. In two cases the end of the outer fragment lay underneath the inner one and both were directed upward and backward. The outer end of the inner fragment is acted upon more strongly by the sterno-cleido muscle than by any other, the effect of which is to draw it upward, and this effect is increased by the pressure of the outer fragment when that is forced in front of and below the other, so that whenever the two fractured surfaces leave each other the inner fragment is likely to incline upward.

The opinion has been held in a few cases that the injury was a separation of the epiphysis rather than a fracture, but there appears to be no warrant for the view, since the epiphysis is very thin, not more than a scale, its point of ossification does not appear until the twentieth year, and consolidation is complete within a year or two thereafter.

Multiple Fractures.—But few cases are recorded in which the bone has been broken in two or more places; in some the fracture was by direct, in others by indirect, violence. Both fractures have been found in the middle third, but more commonly they occupy different thirds. When one fracture has been in the acromial, and the other in the inner or middle third, the intermediate piece has not shown much displacement, and each fracture has followed the usual course of a single one; but when the fractures have been within or close to the limits of the middle

third, the displacement has been very notable, and, as in the following case briefly reported by Malgaigne,[1] irreducible.

A little girl suffered a double fracture of the clavicle; the intermediate piece, which was about two centimetres long, was turned so as to lie vertically between the others, and all the efforts made by Malgaigne and Guersant failed to correct the position. Union took place, but with notable deformity.

Complications of fracture of the clavicle consist in injuries to the vessels, nerves, and lungs, and are exceedingly rare, excluding gunshot wounds in which the complications are produced by the ball and not by the fractured bone. Although the subclavian artery is in intimate relations with the clavicle, I find no recorded case of its injury as a complication of the fracture of this bone. Dupuytren speaks in a lecture of having seen two or three cases of aneurism following fracture of the clavicle, and Jacquemier[2] gives a case observed by Blandin, of an aneurism of the acromial branch of the acromial-thoracic artery following fracture by direct violence. Gurlt refers to a case mentioned by Erichsen, as a probable wound of the subclavian artery, but he takes his account from a German translation, and a reference to the original work[3] shows that it was the vein and not the artery that was thought to be wounded.

A few cases are reported of injury to the subclavian or internal jugular vein, in some of which the diagnosis was verified by autopsy. In the museum of St. George's Hospital[4] is a specimen in which the fractured end of the bone was driven through the internal jugular vein. The patient, a youth aged 23, while standing under a tree during a thunder storm was struck by a falling branch and died immediately.

Of the clinical cases that of Sir Robert Peel is perhaps the best known. There was a "comminuted fracture of the left clavicle, below which a swelling as large as the hand could cover, and which pulsated synchronously with the contractions of the auricles of the heart, formed. It was evidently the result of a wound of some large vein, probably the subclavian, by the broken end of the bone." There were severe associated injuries, and the patient died.

A case has been recently reported in which the patient,[5] a man 59 years old, broke the right clavicle in the middle third by a fall upon the shoulder. A large swelling appeared promptly in the supra-clavicular region and extended to the parotid; it did not pulsate, and had a slight intermittent murmur isochronous with the pulse. The arm was paralyzed, and the radial pulse lost. On the following day the pain was less, and the pulse had reappeared. An incision was made, an enormous quantity of blood escaped, and the patient died at once in consequence of the entrance of air into the vein. The fracture was very oblique, from without inwards and backwards, and the vein was torn completely across by the outer fragment. The artery and nerves were not injured.

[1] Loc. cit., p. 466.
[2] Fractures de la Clavicule, Thèse d'Agrégation, Paris, 1844.
[3] Erichsen, Science and Art of Surgery, Am. ed., 1873, vol. i. p. 348.
[4] British Medical Journal, 1873, vol. ii. p. 82.
[5] Progrès Médical, 1882, No. 16.

Erichsen[1] reported a case of supposed compression of the subclavian vein by one of the small fragments of a comminuted fracture produced by direct violence, but admits that the autopsy showed no signs of such compression, and that the only reason for suspecting it was the gangrene of the arm which appeared on the second day and led to amputation and death by pyæmia. He refers in passing to a case of laceration of the subclavian vein that had been brought to the University Hospital a few years before, but gives no details.

Finally, Annandale[2] once felt justified in cutting down upon a simple comminuted fracture to remove a fragment which he feared was pressing upon the subclavian vein, and might cause it to ulcerate. The patient died in consequence, it is said, of associated head injuries.

Gurlt gives four cases of probable injury to the brachial plexus by the broken clavicle, but adds that in the absence of direct examination of the parts we must remain in doubt as to the exact character of the lesion and of the mechanism by which it was produced. Another case is reported by Mercier,[3] fracture of the middle third with immediate and persistent paralysis of the arm. The accident was caused by the slipping of a large cannon, the patient, a sailor, being caught between the muzzle and the side of the ship. Mercier thought the inner end of the outer fragment had torn the nerve trunks. In three of Gurlt's four cases the paralysis and numbness disappeared wholly or in part under treatment. In the remaining one it persisted.

Injury to the lung, as evidenced by emphysema, has been recorded in five cases where this symptom seemed to be demonstrative, and in two others in which it is much more likely that the emphysema was due to the introduction of air through a wound of the soft parts.

The first five cases are those of Vigarous, Velpeau, Huguier, Rühle, and Mercier. All except the fourth, Rühle's, are described with all the details that are obtainable in the thesis of Mercier above mentioned. Rühle's is mentioned by Bardeleben[4] in a foot-note, as an oral communication by Prof. Rühle to the effect that he had known after fracture of the clavicle and displacement inward of the outer fragment a notable emphysema to appear immediately without fracture of the rib. Velpeau[5] says of his case only that "the outer fragment had been pushed so far by the fracturing cause that an enormous emphysema of the entire trunk ensued," and that he could recognize no fracture of the ribs. The patient appears to have survived. In Huguier's[6] case the clavicle was broken by a fall from a height of twenty feet; the patient was brought to the Hôpital Beaujon presenting a considerable emphysema of all the left side of the chest in front and behind, without fracture of the ribs or external wound. There was hæmoptysis the next day.

Vigarous's[7] patient had his clavicle broken by a blow from the shaft of his wagon while trying to stop his horses which had taken fright at a

[1] British Med. Journ., 1873, vol. i. p. 637.
[2] Brit. Med. Journal, 1873, vol. ii p. 82.
[3] Des Complications des Fractures de la Clavicule, Thèse de Paris, 1881.
[4] Lehrbuch der Chirurgie, 7th ed., 2d vol. p. 405.
[5] Anatomie des Régions. [6] Gaz. des Hôpitaux, 1847.
[7] Œuvres de Chirurgie, Montpellier.

wolf in the road. His breast, head, and neck swelled immediately, and there was so much dyspnœa that he was obliged to lie upon the ground. He remained thus for three hours and was then seen by the surgeon, who found the chest and neck two and a half times as large as normal, and says he had never before seen anything so hideous, so monstrous. The patient was bled as often as it was thought he could bear it, bandages were applied, and a great variety of liniments and decoctions rubbed over him, but without improvement. Narcotics failed to give him rest or to quiet his cough, the pulse became frequent and small, the respiration hurried, and the patient was evidently approaching his end. The emphysema had spread to the arm and hand, the eyelids were enormous, and the lips three inches thick and everted. The family then assented to the proposition that had been made a few days before, and the surgeon made an incision three inches long through the skin over the fracture. In a week the emphysema had entirely disappeared, and the patient recovered.

In Mercier's case the patient, a woman 60 years old, was brought to the Hôpital de la Charité, Paris, service of Desprès, on the 30th May, 1881, with a fracture of the right clavicle at the junction of the outer and middle thirds caused a week before by the fall of a shutter. The emphysema occupied the upper portion of the body but not the head; the patient suffered somewhat with dyspnœa but made no complaint of pain and would not wear any dressing. She said the dyspnœa was greatest during the first three days following the accident. The physical signs of pneumothorax were not present; there was no fever, no cough, no hæmoptysis, no external wound. The emphysema disappeared in three weeks, and the patient left the hospital June 22d, the fracture not yet united.

The anatomical demonstration of the immediate agency is lacking in all these cases, but the notes in all but one show that the surgeons were mindful of the possibility that a fracture of a rib might coexist and might have been the cause of the wound in the lung, and that they were unable to detect such a complication. In most of them, too, mention is made of the depression of the outer fragment, and as the relations of the clavicle to the upper portion of the thoracic cavity are such that it is not difficult to admit the possibility of a wound of the apex of the lung by the broken bone, I think the clinical evidence may be accepted as sufficient.

Etiology.—The clavicle may be broken by muscular action, by direct violence, or by indirect violence. Gurlt, writing in 1864, had collected twenty cases of fracture by muscular action, and the list has been increased somewhat subsequently by the experience and researches of Delens. In the paper above referred to (*Archives Générales*, 1873) he collected eight cases of fracture of the inner end of the bone, and in a subsequent one (*Arch. Gén.*, 1875, i. p. 257) he collected nineteen cases of fracture of the body of the bone in this manner, three of which were personal. Gurlt asserts that this variety of fracture is found most frequently in the middle third of the bone, but his cases are so lacking in details that only a few of them can be used to determine this point.

The efforts by which the fractures were caused were various: lifting

a heavy weight; striking with the hand, a whip or racket; making a vigorous effort that involved the contraction of many muscles, as in Legros Clark's case of a lad who, while swinging by the feet from a trapeze, tried to raise himself so as to seize the bar with his hands; the clavicle broke in its inner third during the effort. It is probable that the clavicular fibres of the deltoid and pectoralis major are the most efficient agents in producing this fracture, since their contraction tends to draw the inner portion of the clavicle downward and outward toward the humerus when the arm is fixed, a direction that corresponds, as has been already said, with the displacement found after fracture in the inner third.

Closely allied to these cases are those in which the fracture has been produced by a blow or other force acting at the hand; thus, an old woman broke her clavicle by closing the door of a wardrobe forcibly, and a lunatic at Bicêtre broke his by striking violently with a heavy stick against some iron bars.

In a very few of the cases the fracture has been produced by two efforts, or a blow and an effort, separated by a longer or shorter interval; the patient feels pain at some point in the clavicle after a fall or a blow or an effort, which persists perhaps, but is not severe and does not interfere with the use of the arm; and then in a few days, after another violence or effort, the bone breaks. If the second violence were sufficient in itself to account for the fracture, the first one might be regarded as a mere coincidence, but it has generally been less than the first.

Direct fractures are produced by very various causes, and may occur at any part of the bone, but most frequently in the middle and outer thirds. The commonest form of violence is a blow falling upon the centre of the bone in a direction that is backward and downward.

Indirect fractures, which constitute the great majority, are most frequently produced by a fall upon the hand, elbow, or shoulder, the arm being extended and the muscles rigid. In a few cases the fracture has been caused by the sudden depression of the shoulder, by which the clavicle was bent over the first rib. Malgaigne[1] reports one: an incomplete fracture at the middle of the bone due to the slipping of a burden from the shoulder to the arm; and Polaillon[2] another: a man who held the end of a lever which was to receive part of the weight of a heavy stone, the stone slipped suddenly upon the lever and drew the arm which held it downward. The man heard a snap and felt pain in the shoulder; the clavicle was broken in its middle third.

The clavicle has been broken in a number of cases during intra-uterine life by external violence, and occasionally by the midwife or obstetrician during parturition.

Simultaneous fracture of both clavicles is, as might be expected, a rare accident. Malgaigne collected six cases, one of which came under his own observation; Gurlt added fourteen to this list, and Hamilton two; Hurel's thesis contains two others, and Polaillon says he found seven reported in French journals and observed one himself. Of these last eight I can identify four as found also in the other lists, leaving a total

[1] Loc. cit., p. 463.

[2] Loc. cit., p. 679.

of twenty-eight cases, in eight of which, however, most details are lacking. In Hamilton's two cases the patients were young boys; one of Gurlt's was a five year old girl and another was a woman; all the rest appear to have been men. Three of the fractures in Hamilton's two cases were incomplete. In position, symptoms, and mode of production these double fractures do not differ materially from single ones. Of the twenty cases in which the mode of production is given, it was in eight a force acting upon both shoulders in the transverse diameter of the body, and in three it was the caving in of an embankment, the mechanism probably being the same. In two it was by direct violence; in one of them a wounded soldier during Napoleon's retreat from Russia was set upon by the Cossacks and pounded with the butts of their guns; in the other a groom was kicked by a horse, each hoof breaking a clavicle. The others were indirect or combinations of direct and indirect fractures. In one case one clavicle was broken by direct violence, the blow threw the man to the ground and caused indirect fracture of the other; in another the patient fell and broke one clavicle, and while lying on the ground was run over by a wagon which broke the other by direct violence.

In three of the cases collected by Malgaigne, union failed in both bones, and he has left a very complete account of the resultant disability in one of them which was under his own care. In the others there was apparently but little permanent interference with the functions of the arms. In recent cases there is sometimes considerable dyspnœa, which Hurel thinks is due to the weight of the arms and shoulders upon the thorax, aided perhaps by the loss of power of the accessory muscles of respiration, those which pass from the neck or thorax to the clavicle and scapula. This dyspnœa is relieved by the dorsal decubitus if the shoulders rest upon a firm support. The condition of Malgaigne's patient on examination three years after the accident was as follows; the shoulders appeared to be below, in front, and on the inner side of their normal positions, the shoulder-blades stood out posteriorly three or four inches from the chest-wall and were inclined forwards and outwards, and the upper part of the chest seemed much contracted. The clavicles were broken at the centre, and the outer fragments were below and behind the inner ones. The shoulders could be drawn back slightly, but not enough to overcome the displacement forward, and they could be drawn forward so far that they were separated by an interval of only three inches, measuring across the chest. The arms could be raised to the horizontal line in front and on the side, but not behind.

Symptoms and Course.—The rational and physical signs common to most fractures are found in those of the clavicle. These are the deformity, mobility, and crepitation, the localized pain, and the diminution of function. Besides the deformity due to the displacement of the fragments, there is also that which is produced by the falling inwards of the shoulder and which is most apparent when viewed from behind, and with it goes a very noticeable projection of the posterior border and inferior angle of the scapula. These signs are of course most marked in cases of complete fracture with overriding of the fragments; in fractures of

the inner and outer thirds they are usually less marked, or even absent, because the average displacement is less.

In fractures of the middle third there is usually displacement of such a character and extent that there is no difficulty in recognizing it and its cause; the fragments can be separately grasped and moved upon each other. Crepitation, however, is not always produced by this manœuvre, for the broken surfaces may not be in contact, and in order to get this symptom it is necessary to have the shoulder drawn backward and outward, so as to reduce the displacement.

The fixed pain is a valuable sign in partial fractures and in fractures without displacement, and it may be the only one that is present immediately after the injury; the appearance within a week of a firm oval mass at the point where pain was felt confirms the diagnosis of fracture. The only probable source of error in such a case would be a periostitis due to direct violence which might give rise to a similar lump.

The interference with function seems to be largely the consequence of the pain which makes the patient unwilling to move the arm, rather than of any mechanical defect produced by the fracture. It was long taught that a patient with a broken clavicle could not raise his hand to his head, but this is so far from being the fact that Velpeau declared he had not met with two cases in twenty years, in which there was this disability. The patient can usually move the arm quite freely backwards and forwards, but cannot raise it or adduct it without pain, and if asked to put his hand on his head, will usually flex the forearm, incline the body, and bend down his head to accomplish it. The fracture and displacement are not entirely without influence in this limitation of the movements, but they are not wholly responsible for it. Hurel,[1] who profited by his internat at the hospital for convalescents at Paris, to examine the later condition of patients with this fracture, found the movement of circumduction of the arm the last to be regained, and that a shortening of half an inch or more delayed complete recovery considerably beyond the time that was sufficient for it when the shortening was less or absent.

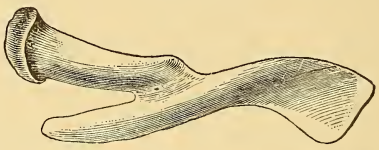
The patient's appearance is often quite characteristic; he sits with his body and head inclined towards the injured side and supports the elbow or forearm with the other hand, and some surgeons have held that the diagnosis could be made by the simple inspection of the posture. The only cases in which the diagnosis can well remain in doubt after even a brief examination are those of incomplete fracture, and some of fracture close to either end of the bone. The latter may be mistaken for dislocation; in fact, one was so mistaken—a fracture of the sternal end under the care of Béclard, at La Pitié, the real character of the lesion appearing at the post mortem. This error may be avoided if the outline of the bone can be accurately traced, but in two cases of dislocation of the acromial end of the clavicle with slight occasional crepitation, I have found it impossible to determine positively the seat of the accompanying fracture, which was, probably, a partial one, running into the joint.

The progress of the fracture is extremely simple and is rarely dis-

[1] Les Fractures de la Clavicule, Thèse de Paris, 1867.

turbed by complications or dangers. Union is usually firm by the end of the fourth week, sometimes much earlier, and failure of union is rare. Displacement and shortening, however, are the rule, only those cases, apparently, being exempt in which the line of fracture is transverse and there is no displacement at first. The amount of the shortening may vary from a fraction of an inch to one and even two inches, and it may be produced by angular displacement, or by overriding, or by both, as in figure 169.

Fig. 169.



Fracture of the clavicle. Union with extreme displacement.

The complications that may occur in the course of the repair are the ordinary inflammatory ones that may arise at the seat of fracture in consequence of the bruising of the surrounding parts, or of the failure to immobilize the fragments, or special ones due to the pressure of the fragments or callus upon the vessels and nerves. Cases have been already given in illustration of these complications when produced at the time of the accident; those of later occurrence are very exceptional, although Delens[1] intimates a belief that the diminution of power observed in some cases after recovery may be due to compression of the nerves by an exuberant callus. Besides his own case Delens was able to find only one other, Polaillon's.[2] A few cases in Gurlt's chapter upon fractures of the clavicle may perhaps be instances of paralysis due to the pressure of a large callus, but it is not possible to distinguish positively between the primary and the secondary effects. Delens's case is very satisfactory. The patient was brought to the hospital, January 1st, 1881, with fracture of the left clavicle and two ribs. The arm was placed in a Mayor's sling, and union was complete by the end of the month. The patient returned on the nineteenth of March, complaining of great loss of power in the left arm; examination showed marked overriding of the fragments, the outer lying in front of the inner one, with a hard firm callus two inches thick, atrophy of all the muscles of the left arm, and passive congestion of the skin of the hand; the pulsations of the left radial artery were much weaker than those of the right. The posterior and lower portion of the callus was removed by operation, the pulsations of the radial artery and the appearance of the hand at once became normal, and the patient gradually recovered the use of the limb.

In another case Gosselin removed a portion of callus which had caused persistent ulceration of the soft parts covering it. A prompt cure followed.

[1] De la résection d'un cal de la Clavicule comprimant les vaisseaux et les nerfs sous-claviers, in Archives de Médecine, Aug. 1881, p. 170.

[2] Loc. cit., p. 696.

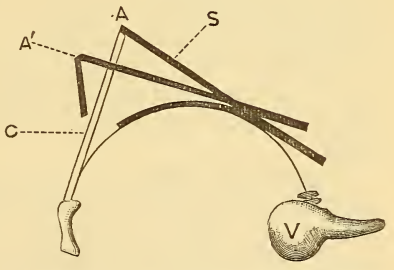
Ossification of the coraco-clavicular ligament has been observed in several cases after fracture in the outer third. No description is given of the modifications, if any, of the functions of the part produced by this ankylosis.

Failure of union is rare. The fact that in three of the six cases of fracture of both clavicles collected by Malgaigne, the bones did not unite, led that author to believe that this double fracture predisposed strongly to failure of union; but as no similar failure has been since recorded, and as the failure in at least two of these cases appears to have been the result of the lack of treatment, the opinion lacks support. A few cases of failure of union after fracture have been recorded, and it is worthy of note that it does not appear to have resulted in any diminution of function; in one case carefully examined by Hamilton where there was ligamentous union and overriding to the extent of half an inch the arm on the affected side was in every way as strong and as fit for use as the other. In the recorded cases of pseudarthrosis the fracture has generally been in the middle third, rarely in the inner one. In only two cases has the pseudarthrosis received operative treatment. The seton was used in both, and successfully.

Treatment.—The indications for treatment are to reduce the displacement and to prevent its recurrence. The means by which they are to be met do not differ materially in the different fractures, but in describing them I shall have mainly in mind fractures of the middle third.

As has been already said, the shoulder and outer fragment are usually displaced inward, forward, and downward, and the outer end of the inner fragment is displaced upward. The force which produces the first displacement is the weight of the shoulder. It must be remembered that the shoulder hangs out from the chest as a sign hangs out from the side of a house; the scapula and clavicle are two lateral supports, and the trapezius muscle is a suspensory one. A glance at figure 170 shows how the fracture of the clavicle removes one lateral support, and how the weight of the shoulder, being no longer supported upon that side, swings forward and inward upon the posterior border of the scapula as a centre, or rather upon the under surface of that bone as it lies in contact with the round chest wall, until a new equilibrium is found. This movement of rotation carries the posterior portion of the scapula away from the back at the same time that it brings the anterior portion nearer the front, and as the upper part of the chest is dome-like and not simply cylindrical, and as the movement, the change of position, takes place therefore in a vertical as well as in a horizontal plane, the shoulder drops and the inferior angle of the scapula rises, by comparison at least, if not actually. Reduction, therefore, is to be

Fig. 170.



Mechanism of displacement after fracture of the clavicle. A, acromion; C, clavicle; S, scapula; A′, position of the acromion after the fracture.

accomplished by carrying the shoulder back to its former position, and retention by supplying the support previously given by the clavicle. These indications have been clearly understood since the time of the earliest writers, but it has been found very difficult to embody them in practice, because there is no means of acting in the desired manner upon the shoulder that does not involve an amount of discomfort that patients will not ordinarily submit to. Moreover, in some cases surgeons have lost sight of the fact that the position of the arm is a secondary one, its importance being due solely to its use as a means of acting upon the outer end of the scapula, and that it is useless to press the elbow upward unless the scapula is left free to be raised by that pressure. It is entirely useless to bind the elbow to the shoulder on the same side ; such dressings do not raise the scapula.

One of the methods of reduction employed by Hippocrates resembles in principle very closely the dressing suggested by Velpeau and employed with much success by him and others. He placed the hand of the affected side upon the opposite shoulder and then pressed the elbow forcibly upward and outward. As the arm lies thus across the chest its long axis is exactly in the direction in which pressure should be made to overcome the usual displacement. Another method employed by Hippocrates was to place the patient upon his back with a small hard cushion between his shoulders, and then to press backward upon the acromion or the head of the humerus while the elbow was pushed up by an assistant. Paulus Ægineta made extension by drawing the arm upward and outward, and counter-extension by the neck or other arm, and he also recommended the axillary pad with the elbow brought close the side. Guy de Chauliac placed his knee between the patient's shoulders and drew them backward. These methods are the types of all that have since been used or that are now in use. A modification introduced by Chassaignac deserves mention. Having observed that the displacement could be reduced by extreme elevation of the shoulder, he proposed the following method: the surgeon places his breast against the shoulder of the uninjured side, clasps his hands under the opposite elbow and draws it forcibly upward. The principal objection to the method is that if the fracture is oblique the reduction cannot be maintained.

Reduction, in short, is to be sought by carrying the shoulder upward, outward, and backward, acting either directly upon it or indirectly through the elbow, or using the arm as a lever. Polaillon recommends strongly a method based upon the latter principle ; standing behind the patient he passes his hand or forearm into the axilla and draws upward and backward with it, while with the other hand he presses the elbow against the side and thus forces the shoulder outward.

In some cases it is necessary to have these efforts made by an assistant in order that the surgeon himself may be at liberty to make such movements of coaptation as may be needed to overcome the obstacles offered by points or irregularities upon the surface when the line of fracture is transverse or nearly so. In transverse fractures with only angular displacement upward and forward it is sometimes sufficient to make pressure upon the angle.

The physical obstacles that need to be overcome in the treatment are so great, and the success that has attended the different methods has been so moderate that the number of plans that have been proposed and employed is very great, and the history of the treatment shows mainly a recurrence of periods marked at first by elaboration and multiplication of details and precautions and then by the abandonment of them all and the substitution of something very simple. The results obtained by the simple scarf or sling are as good as those furnished by the most elaborate bandaging, and the discomfort to the patient during treatment is much less.

The differences in the methods depend in great part upon the indication which each surgeon has had more particularly in mind, upon the displacement which he sought to prevent. Thus, in some the special object of the dressing is to maintain the shoulder elevated, in others to hold it back, and in others again to draw it outward. The type of the first class is a band passing under the elbow and forearm and around the neck, the forearm lying across the chest. That of the second is a posterior transverse splint to the ends of which the shoulders are made fast, or an anterior transverse splint pressing the shoulder back. That of the third is the axillary pad used as a fulcrum to force the shoulder out by pressing the elbow in.

When the patient is sufficiently desirous to avoid any visible irregularity in the outline of the clavicle to bear the discomforts of a prolonged rest in bed without change of position, and when the displacement can be reduced, treatment in the recumbent position holds out the best prospect of recovery without deformity. The patient should be placed upon his back (or rather upon *her* back, for it is not probable that any one but a lady whose social position requires her neck to be left at times uncovered will submit to this confinement), upon a firm mattress with the head bent forward so as to relax the sterno-cleido-mastoid upon the injured side, and the elbow fastened to the side or chest or raised upon a cushion so that the weight of the arm may tend somewhat to force the shoulder upward and backward, anatomically speaking. It has been recommended also that a firm narrow cushion be placed along the spine between the shoulder blades, and Robert preferred to have the patient lie not entirely flat upon the back, but inclined slightly toward the uninjured side. In one case digital pressure was made upon the fragments throughout the treatment to insure accurate coaptation. Malgaigne suggested that blunt hooks with a strap fastening them to the elbow, or double hooks like those he used in fracture of the patella, might perhaps be substituted for the fingers of the assistant. The position must be kept practically unchanged for at least two, and probably for three, weeks.

Quite recently Langenbuck[1] has used the silver suture. The patient was a boy ten years old, the fracture at the junction of the outer and middle thirds. The fragments were fastened together with silver sutures, both ends cut short, and the periosteum united with catgut

[1] Deutsche Med. Wochenschrift, Jan. 28, 1882.

Fig. 171.

Fracture of the clavicle. Mayor's scarf.

sutures. Antiseptic dressings and the Desault bandage were used. The result is said to have been very good. The scar left by the operation would probably be considered as objectionable a disfigurement as union with the average displacement.

Mayor's Scarf or Sling (fig. 171) is made of a square of muslin the diagonal of which is long enough to extend easily around the body. The forearm is flexed at a right angle and laid across the breast; the cloth, folded diagonally, is laid over it and tied around the body so that its folded border runs horizontally around an inch or two above the forearm, in front of which the cloth hangs down. The free point of the triangle is then brought up between the forearm and the body, and the two folds of which it is composed are secured, one on either side of the neck, by bands attached to the scarf behind and brought forward over the shoulder.

A modification which makes this more secure was used by Gosselin. The forearm rests between the folds of the triangle, the folded diagonal of which thus forms the lowest part of the dressing, while its ends are tied around the body as before. The folds that form the third point are also secured as before, or, if long enough, are tied together about the neck. Richet sought to give additional solidity by adding bands of adhesive plaster, passing them under the elbow and across the opposite shoulder.

Fig. 172.

Velpeau's dressing for fracture of the clavicle.

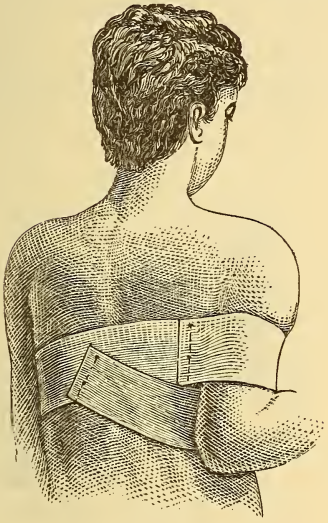
This method is suitable for fractures without much displacement, especially for those in children with untorn periosteum.

Velpeau's dressing (Fig. 172) is more secure. It is made with a long roller bandage. The elbow is brought well in front of the chest and the hand placed on the opposite shoulder, and the limb is drawn snugly up towards the neck by successive turns of the roller which, beginning at the opposite axilla, pass obliquely across the back, over the shoulder, in front of the arm, under the elbow, and back to the axilla; after three or four such turns have been placed the bandage is carried circularly around the body covering in the arm from below upward. The turns should be secured by stitching or by soaking in dextrine or plaster.

Sayre's dressing (figs. 173 and 174). A very convenient and popular dressing is the one introduced by Prof. Sayre. It is made of two strips of adhesive plaster, each about three inches wide and long enough to go once and a half around the body; one end of the first strap

is stitched loosely about the arm just below the axilla, and the other carried around the chest from behind forward, as shown in figure 173. The second strap is then carried from the top of the shoulder on the uninjured side across the back, under the elbow, and along the forearm to the shoulder again (fig. 174). The elbow should be drawn back while

Fig. 173.



Sayre's adhesive plaster dressing for fracture of the clavicle. First piece.

Fig. 174.

The same. Second piece.

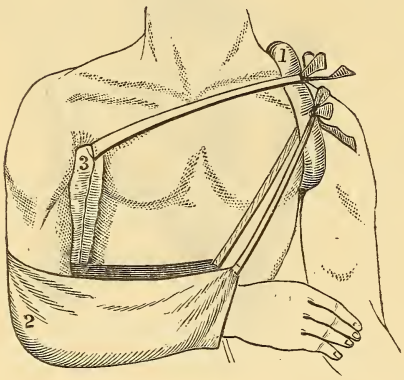
the first strap is applied, and well forward while the second is. It is a convenience to the patient to have the plaster carried past the ulnar side of the hand so as to leave the latter uncovered. The action of the dressing is simply to press the shoulder upward and backward, and its principal advantage lies in the solidity which the use of the adhesive plaster gives; sometimes a turn of a roller bandage is placed under the plaster to prevent irritation or excoriation.

The axillary pad, designed especially to prevent shortening by forcing the shoulder outwards, has been in use for many centuries, and reached its highest development at the hands of Desault, of whose complicated dressing it forms the essential part. He made it of a firm, wedge-shaped cushion stuffed with hair, long enough to reach from the axilla nearly to the elbow, four or five inches wide, and three inches thick. It was placed between the arm and the body with its thick base in the axilla, and the elbow was then brought down and fastened to the side with a roller bandage. Numerous other turns of the bandage were carried under the elbow and over the shoulders to force the arm upward and backward. Desault's dressing was cumbersome and liable to slip, and the axillary pad has on more than one occasion caused gangrene of the arm by obstruction of the circulation, or paralysis by pressure upon the nerves. As now used it is smaller and softer, but, I

believe that whenever it is large and firm enough to accomplish its object, it is dangerous, and whenever small enough to be free from danger it is useless. It still forms part of many dressings, but I do not think its use in its more recent form can be justified theoretically, or that the results obtained by it are better than others. I shall, therefore, mention only one dressing of which it forms part, a dressing that has been highly spoken of in the past and which is still very popular, I believe, in Philadelphia. It was introduced into the Pennsylvania Hospital by Dr. George Fox, in 1828.

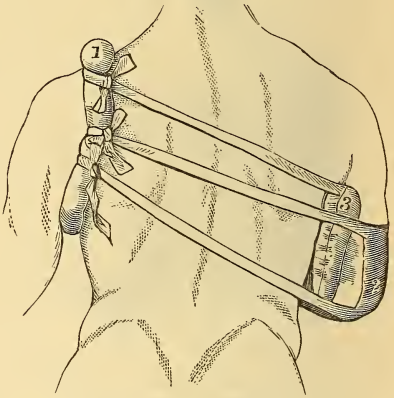
Fox's dressing (figures 175, 176) consists of an axillary pad, a stuffed leather ring, and a sling. The ring is passed over the arm of the

Fig. 175.



Fox's dressing for fracture of the clavicle.

Fig. 176.



Fox's dressing for fracture of the clavicle.

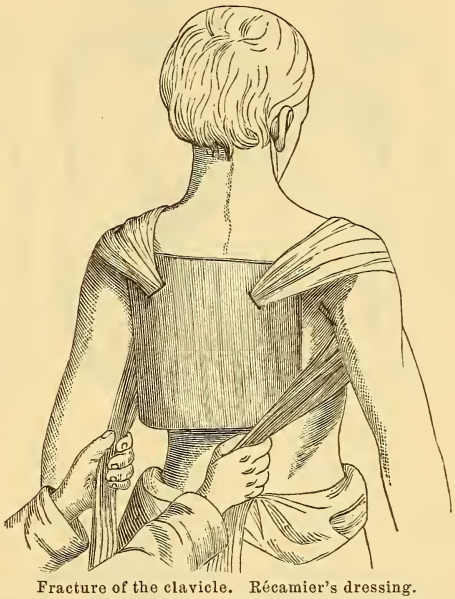
uninjured side to the shoulder, and the pad and sling are attached to it by straps, as shown in the accompanying figures. Dr. Agnew speaks highly of its value in the treatment of fractures of the sternal or acromial end of the bone.

Papini's Brace.—An attempt to meet the same indication by means of a fixed brace has been made by Papini, and the instrument seems to be well adapted to its purpose. It consists of an artificial clavicle of wood made fast to the body and shoulder by a jacket and armlet of leather. The arm is secured to the side and the elbow held up by a roller bandage. It is adjustable, so that the shoulder can be pressed back to the desired extent.

The dressings which are intended mainly to draw the shoulder backward are modifications of the figure-of-8 bandage and the posterior and anterior splints. The simple figure-of-8 carried across the back from one shoulder to the other, is, if not actually harmful, certainly inefficient. A modification suggested by Récamier amounts almost to a posterior splint. He placed a large, hard square cushion (fig. 177) between the shoulders behind and carried a bandage from each upper corner over the shoulder and under the axilla back to the lower corner. Moore, of Rochester, applied the bandage so as to include the elbow as well as the

shoulder of the affected side, seeking to make the fibres of the pectoralis major tense by drawing the elbow backward. The bandage in his dressing (fig. 178) should be about two yards long, its centre is placed under the olecranon, the forearm being flexed at a right angle, the end that is next the body is carried up between the arm and the side, in front of and over the shoulder, across the back and under the opposite axilla; the other end is carried around the outer side and front of the elbow, then between it and the side to the back, and across the back to the opposite shoulder where it is made fast to the first end. The elbow must be drawn backward and pressed upward. Hamilton expresses approval of the principle of this dressing, but finds its use troublesome to the patient. I do not think it is worth while in any dressing to seek to draw down the inner fragment through the agency of the pectoralis major.

Fig. 177.



Fracture of the clavicle. Récamier's dressing.

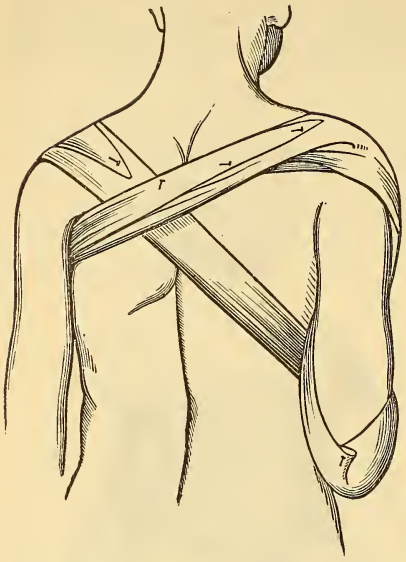
Posterior splints are seldom used now. They have been made in the form of a cross, against the arms of which the shoulders were drawn back, and as iron, wooden, and pasteboard splints crossing the back and extending usually beyond the shoulders, so that the traction of the bandages by which the shoulders were made fast should be exerted in an outward direction as well as backward.

Anterior splints, made of gutta percha or metal, and moulded to the front of the chest from one shoulder to the other, have been used with the same object, and the attempt has been made to use plaster of Paris in the same manner, pouring it over the front of the shoulder and chest to solidify while the fragments are held in position.

I am not aware that the plaster-of-Paris jacket has been used for this purpose, and I have had no suitable opportunity to make trial of it except in the somewhat similar dislocation of the acromial end of the clavicle, but I think it would furnish a fixed point that could be made useful by fastening the shoulder to it by additional turns of the bandage.

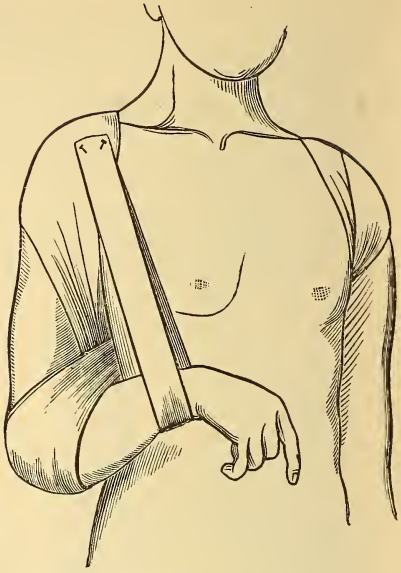
It is very apparent upon examination of the history of this subject, that while many different dressings may give good results in certain cases, none can be depended upon to do so in all, and that the displacement, the shortening, which is the rule, is the result in some cases of forces which cannot be effectually controlled, of the obliquity of the fracture, and not infrequently of the indocility of the patient, who, finding himself incommoded by the dressing, shifts it slightly, but often,

Fig. 178.



Moore's dressing for fractured clavicle.

Fig. 179.



Moore's dressing for fractured clavicle.

until he obtains ease at the sacrifice of the object it was applied to secure.

If the fracture is without displacement, especially the subperiosteal fracture of children, or if the displacement shows but little tendency to recur after reduction, the simple scarf or sling or Sayre's dressing will answer every purpose.

If, on the other hand, the tendency to displacement is great, the choice of a method of treatment will depend largely upon the character and wishes of the patient. If he is indifferent to the deformity or intolerant of restraint, it is useless to attempt more than a simple dressing; but if he is willing to submit to the confinement, the fracture may be treated by dorsal decubitus and digital pressure with a fair prospect of success.

If the displacement is irreducible, as sometimes happens, and without much tendency to increase, a simple dressing is sufficient.

In simultaneous fracture of the two clavicles, the dorsal position is strongly to be recommended.

It is well to place in the axilla a pad of cotton wrapped in a compress to absorb the moisture and keep the opposing surfaces from contact with each other; and for the same reason a compress should be placed between the arm and the body, wherever the two would otherwise be in contact.

If an axillary pad is used, particular attention must be paid to the condition of the circulation and innervation, and the examination must be made twice or three times a day at first.

The dressing should be worn for from fifteen to twenty days by children, and twenty to thirty days by adults.

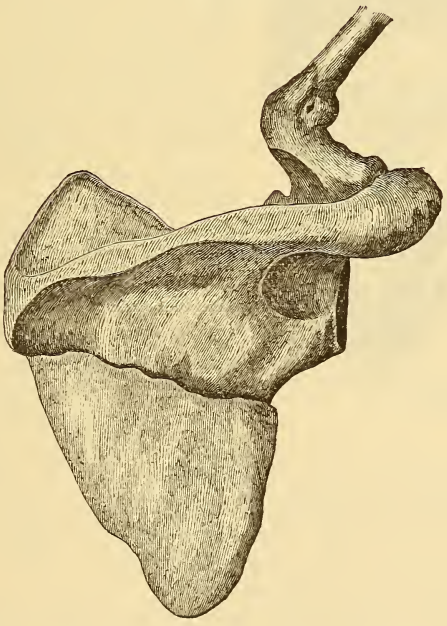
CHAPTER XX.

FRACTURES OF THE SCAPULA.

Fractures of the scapula are comparatively rare, about one per cent. of all fractures according to the best statistics at our command. They are six times as common in men as in women, and in the great majority of cases the patients have been between twenty and fifty years of age.

The size and shape of the bone, and the presence of three irregular and prominent apophyses permit a diversity of fractures differing so greatly in their mode of production and symptoms that it becomes necessary to consider them separately. Most writers in the last hundred years have made from six to eight groups as follows: 1st, fractures of the body;

Fig. 180.



Transverse fracture of the sternum. Fracture of the clavicle; union.

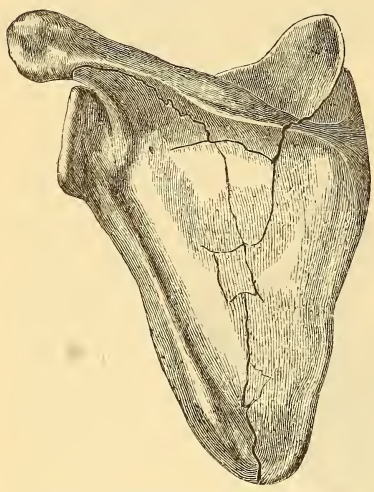
2d, fractures of the inferior angle; 3d, fractures of the upper angle and supra-spinous fossa; 4th, fractures of the spine; 5th, fractures of the acromion; 6th, fractures of the coracoid process; 7th, fractures through the surgical neck; 8th, fractures of the glenoid cavity. Of these

varieties the 1st, 4th, 5th, and 7th are by far the most common, the others are extremely rare.

1. *Fracture of the Body of the Scapula.*—Fractures of the body of the scapula are single or multiple. The former are confined to the subspinous fossa, and the direction of the line of fracture is transverse or oblique. The fragments may preserve their normal relations to each other or there may be displacement, the lower fragment shifting to either side of the upper one and overriding for a greater or less distance. This overriding is most marked on the axillary side and is due apparently to muscular contraction, while the lateral displacement is the result of the continued action of the fracturing force. In some cases the fragments have united after transverse or oblique fracture in such a position that they touch or override at one side and are separated at the other.

In multiple fractures the lesion is extremely variable, the fracture may be "starred," or comminuted, some of the lines may be incomplete, and the main one may be longitudinal; the only condition, apparently, under which longitudinal fracture is met with (fig. 181). Gurlt doubts if a simple longitudinal fracture was ever known, although he quotes a case from the *Lancet* (1862, vol. ii. p. 116) described as such.

Fig. 181.



Multiple (longitudinal) fracture of the scapula.

Malgaigne describes a case of supposed partial fracture, the diagnosis being made during life. The central portion of the bone was found depressed after a blow, with a sharp, well-defined, bony margin on the spinal side, and rising gradually to the level of the bone on the other; no crepitation or abnormal mobility. Dr. Hamilton describes a partial fracture or fissure found in the scapula of an Oneida Indian who died of injuries received a few months previously in a street fight. The fissure ran from a point on the posterior border three-fourths of an inch below the spine transversely across the body of the scapula for $1\frac{3}{4}$ inches. There was no displacement and no union, but there was a ridge of callus along each side of the fissure. Gurlt gives a figure of a specimen showing what seems to be a marked infraction of the body below and parallel to the posterior half of the spine.

The cause of the fracture has always been direct violence, usually a blow or a fall upon some angular object, but in two cases it was caused, with other injuries, by the passage of a locomotive, the patient having fallen between the rails and been squeezed between the ground and the ash-box as it passed over him.

The objective symptoms which may be met with are irregularity in outline, abnormal mobility, crepitation, and ecchymosis. The posterior

border of the bone can be brought into prominence by carrying the forearm across the chest or behind the back, and then if the finger is passed along it a transverse or oblique fracture with displacement will be certainly recognized. Abnormal mobility and crepitation are not so readily made out, the best plan is to pass the fingers if possible under the inferior angle and thus ascertain if it moves independently of the rest of the bone. To detect crepitation the palm of one hand should be placed over the bone and the arm moved freely in different directions. In multiple or partial fractures with depression the adjoining edge of bone may be felt, as in Malgaigne's case, if the patient is not too fat or muscular. The precaution should always be taken to make a comparison with the other scapula, and the normal ridges along the borders and at the base of the spine should be borne in mind. Ecchymosis unless due to the action of the violence upon the soft parts, seldom appears until after the lapse of a few days. Emphysema was spoken of as a symptom by Petit, but has been noticed by no subsequent observers; possibly it was due in his cases to concomitant fracture of the ribs and wound of the lung.

Localized pain on pressure and on movement of the arm is a constant symptom, and may make it impossible for the patient to extend his arm horizontally and directly forward because it is so much increased by the contraction of the muscles concerned in this movement.

The course in the simpler cases ends in recovery in four or five weeks, usually with preservation of function even if union has taken place with some unreduced displacement. Multiple fractures are more dangerous because of the greater probability of suppuration at or in the neighborhood of the fracture, and of course if the fracture is a compound one the danger is still greater. In a very few instances there has been much disability due to failure of union or to union with displacement and exuberant callus. Gurlt quotes an example of the former in which the patient was unable to raise his hand to the back of his neck, and one of the latter in which the disability was almost complete and all communicated movements of the arm and shoulder painful.

Treatment.—In simple fracture without displacement no other treatment is needed than immobilization of the arm and shoulder during the length of time necessary for consolidation. If displacement exists it must be corrected if possible, but no rules have been laid down by which this may be accomplished, no special principles even established by attention to which the attempt is made more likely to succeed. Great diversity exists in the recommendations made by different writers, and unfortunately each has to admit the possible failure of his method. Malgaigne, indeed, after an elaborate description of the mechanism of displacement and of the means by which it should be reduced and prevented, admits that he had never been able even to reduce it, and that sometimes the manœuvres and positions which seemed best calculated to diminish it only increased it. The surgeon therefore should seek to recognize the character of the displacement as clearly as possible, and then should try to reduce it by placing the arm and shoulder in various positions and pressing upon the fragments with his hands in the directions indicated by the displacement. When the latter is reduced as far as possible the arm and shoulder must be immobilized by bandages that raise the elbow

and fix it to the side, and broad strips of adhesive plaster should be laid across the scapula to aid in its immobilization. Moulded splints of pasteboard, gutta percha, and plaster of Paris have been suggested and employed, but they do not furnish enough additional security to compensate for the discomforts they may cause.

In comminuted fractures the principal indication is to prevent the severe inflammatory reaction which is so likely to follow the bruising and laceration produced at the same time by the extreme violence that has caused the fracture. If the fracture is compound it must be explored through the wound and treated in accordance with the principles elsewhere laid down, and I believe that it is prudent in such cases to remove partly adherent fragments which could be safely left after fracture of other bones, whenever by such removal a free outlet that would otherwise be lacking is supplied to matter that may accumulate on the under (costal) surface of the bone. The experience furnished by fractures of other flat bones, the skull and sternum, shows the probability of suppuration on the under side, and in a few cases of fracture of the scapula pus has formed in this manner and caused much trouble by burrowing down the side. In one case of simple fracture the surgeon felt justified in cutting down upon the bone and removing a large number of fragments, but the practice has not been approved by any one who has quoted the case, at least not to the extent of laying it down as a rule for general application.

Fractures of the Inferior Angle.—These are included by some surgeons, and with good reason, in the group of fractures of the body of the scapula, from which they differ merely by the proximity of the line of fracture to the lowest part of the bone, but as they present a more constant and well-defined displacement which cannot be readily overcome or prevented they deserve separate mention. The recorded instances of separate fracture are not very numerous. Gensoul reported one produced by muscular action; the patient saved himself from falling to the ground while descending a sharp incline, either by catching hold of some support or by falling backward upon his outstretched hand, the abstracts of the report are not very clear upon this point. A triangular piece corresponding to the inferior angle was detached from the scapula and displaced forward and upward, and could be moved independently and with crepitation. Gensoul attributed the fracture to the sharp contraction of the teres major. In other cases the cause has been a fall upon the back.

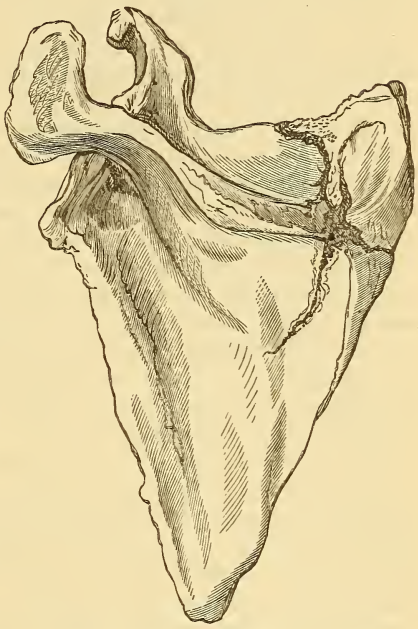
The symptoms, apparently, are clear and unmistakable; displacement of the fragment forward and upward by the combined action of the serratus magnus, teres major, and, according to some, of the latissimus dorsi; abnormal mobility recognized by grasping the fragment with one hand and moving it, or by fixing it with one hand and moving the scapula with the other; and crepitation.

The displacement is difficult to reduce or maintain reduced, because the smallness of the fragment prevents efficient control of it, and the tonicity of the muscles tends constantly to draw it away; but while this insures some deformity it is slight and does not add seriousness to the prognosis. It has been proposed to overcome the displacement by

carrying the upper fragment forward to a position corresponding to that of the smaller one, moving the arm forward and upward so as to make the connecting muscles tense, but those who propose this seem to have overlooked the fact that the lower fragment would be acted upon at the same time, and in the same manner and to the same degree so that the parts would preserve their relative positions and the displacement would remain.

Fractures of the Upper Angle.—These are very rare. Gurlt gives a figure of a specimen preserved in Dresden, and Hamilton, of one in Philadelphia. In the latter (fig. 182) a fissure extends well into the subspinous fossa. In both repair has taken place without much displacement. Gurlt records two cases observed during life; in each the injury was the result of a fall upon the back; in one there was no displacement, in the other the fragment was drawn upward and inward by the levator anguli scapulæ.

Fig. 182.



Fracture of the posterior angle of the scapula. (Hamilton.)

The treatment is to immobilize the arm and shoulder in the position that is most comfortable, securing the scapula with a body bandage or strips of adhesive plaster, and the arm by binding it to the body with the forearm flexed across the chest.

Fractures of the Spine of the Scapula.—There are no known specimens of isolated fracture of the spine of the scapula, and our only knowledge of them is clinical and based upon a few cases. Of these the following seem demonstrative.

A delicate lad, 18 years old, was struck on the side of the head, and fell, striking upon his right shoulder. There was no pain or disability at first, but the next day there was pain in the shoulder which interfered with the movements of the arm. There was mobility of the spine, crepitation, pain at the seat of fracture, no displacement, no swelling. It was dressed with a simple bandage, and was well in a month.

A man 38 years old fell upon the right shoulder; the pain was severe, but the limb was freely movable. Examination the next day showed distinct crepitation along the entire length of the spine of the scapula. The treatment was Mayor's sling, leeches, etc.

Dornec[1] reported the case of a child $2\frac{1}{2}$ years old, that had fallen upon

[1] Dictionnaire Encyclopédique, art. Omoplate, p. 287.

his right shoulder. He continued to use the arm, and it was not until a fortnight afterwards that the mother noticed a lump upon the shoulder and felt crepitation. This lump was very apparent, and could be made to appear and disappear by pressure upon it, or by carrying the shoulder forward; it was distant nearly an inch from the posterior end of the spine. Movements communicated to the inferior angle did not disclose abnormal mobility or cause crepitation.

The treatment is as before; immobilization of the arm in a suitable position, and local antiphlogistic remedies if required.

Fracture of the Acromion.—The alleged frequency of this fracture has been called in question by those who consider most of the museum specimens examples either of a traumatic separation of the epiphysis or of non-ossification. The former would still belong under the head of fractures, and, even if we exclude the others, there are still clinical instances in sufficient number to make the lesion one of the most common. Of 54 cases tabulated by Agnew,[1] in 41 of which the seat of the fracture was stated, 12 were of the acromion, 9 of the body, 10 of the spine, 5 of the neck, 4 of the inferior angle, and 1 of the glenoid cavity. As will be seen, the relative frequency, according to this table, differs somewhat from that quoted above.

The acromion is exposed to fracture by blows received directly upon it, and also through the humerus, as in a fall upon the elbow; and a case was mentioned in Chapter IV., in which it was broken by muscular action. The line of fracture is usually perpendicular to the axis of the apophysis, but is sometimes oblique. It lies most frequently either in front of the acromio-clavicular joint, or at the root of the acromion, rarely at an intermediate point. Gurlt found it from $2\frac{1}{2}$ to 3 centimetres behind the tip of the acromion in six cases, and at the root in only two. In five cases, seen by Hamilton, it was in front of the clavicle in two, at the clavicular joint in two, and behind it in one. The periosteum may remain untorn and the fragment undisplaced.

The symptoms are those of the fracture and of the contusion, if the agency has been direct violence, and as the latter are prominent, and may obscure the former, a fracture may be mistaken for a simple contusion. The signs common to both are ecchymosis, local or extending down the arm, swelling, and pain. The additional signs of fracture are increase of the local pain on pressure and on moving the arm, usually complete inability to abduct the arm, displacement, abnormal mobility, and crepitation.

The displacement varies with the position and extent of the fracture. If the latter involves only the outer end of the apophysis, the displacement is slight and downward by the contraction of the attached fibres of the deltoid, the shoulder loses a little of its roundness in consequence, but the head of the humerus retains its place. If the fracture is near the base of the apophysis, the weight of the arm tends to draw the fragment downward and inward, turning it upon the outer end of the clavicle as a centre, and the shoulder is much flattened. The finger passed along the spine recognizes an irregularity in the outline, usually a de-

[1] Surgery, vol. i. p. 872.

pression of the outer fragment, but sometimes an elevation or a transverse groove or gap in which the end of the finger can rest.

Crepitation can often be got by lifting the elbow directly upward, so as to push up the acromion, or by abducting the arm; and abnormal mobility must be sought by varied manipulations of the apophysis and by moving the arm.

In one of the cases observed by Dr. Hamilton, in which the fracture entered the acromio-clavicular joint, the outer end of the clavicle was displaced upward, in others this displacement has been absent.

The commonest functional disturbance is the inability to raise the arm, although this is not a constant symptom, while the power of rotation is preserved unaltered, even if somewhat painful.

Bony union appears to be the exception, the fragments uniting by a fibrous bond of greater or less length and solidity; the rupture or the preservation of the periosteum must be of almost controlling importance in determining the character of the union. Apparently, bony union takes place only when the fragments remain in close contact. The vitality of the central portion is greater than that of the fragment, for the latter must depend for its blood-supply upon the vessels which penetrate it from its own surface, and some of the specimens show evidences of a more efficient or active effort at repair on the central side. In one case the distal fragment became necrosed and was cast out, apparently in consequence of the excessive inflammation of the overlying soft parts.

The treatment consists in reduction of the displacement by pressing the head of the humerus upward against the acromion, and in preventing its return by securing the arm in the position that proves most efficient and comfortable. Sir Astley Cooper taught that the elbow should be held at a little distance from the side by a pad, in order that the outer fibres of the deltoid should not be made tense and the fragment drawn down by them. The arm must be bound to the body by a dressing similar to those used in the treatment of fracture of the clavicle, one that will raise the elbow and immobilize the arm thoroughly. It should be worn for about four weeks. Additional security is given by the use of fixed dressings, plaster, starch, dextrine, and possibly by a gutta-percha splint moulded to the shoulder.

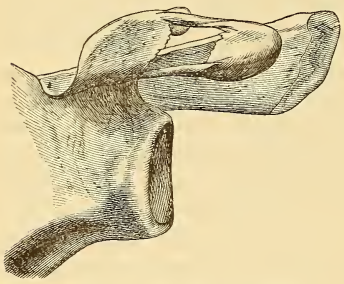
Fracture of the Coracoid Process.—In most instances this fracture has been observed in connection with others of the scapula, humerus, or ribs, or with dislocation of the humerus, the result of severe external violence that was frequently fatal; but it has occurred alone by the same mechanism and also by muscular action. The following example of the latter is quoted by Gurlt, from C. O. Weber. A woman, 38 years old, while wringing out some wet clothes felt something snap under her collar-bone, and found herself unable to continue her occupation. She was very thin, and a fracture of the end of the coracoid process could be felt distinctly. Another example has been more recently reported by Mr. Hulme.[1] A man, 57 years old, was passing through a wire fence on a bank; he slipped, and in falling his left arm caught in one of the wires of the inclosure. He instantly felt severe pain in the fingers, with

[1] Lancet, 1873, vol. ii. p. 737.

loss of power in the arm and inability to raise the elbow. On examination, three weeks afterwards, the coracoid process was found broken and displaced downward. Gurlt collected three cases in which the fracture was caused by moderate violence, and he thinks it may be caused by the impact of the head of the humerus in a dislocation.

The line of fracture is usually about an inch behind the beak of the process, but sometimes is further back, passing close to the upper edge of the glenoid cavity in a line that corresponds so nearly to the position of the epiphyseal cartilage that some observers consider some specimens to be examples of separation of the epiphysis, or even simply of delay in ossification. Normally this conjugal cartilage ossifies at about the fourteenth year. In one of Malgaigne's and in two of Gurlt's cases, the end of the process was also split longitudinally into two pieces, one remaining attached to the tendon of the biceps, the other to that of the pectoralis minor. The displacement is seldom great, because the fragment is prevented from yielding to the action of the attached muscles by the coraco-clavicular ligament; still, in one of the last-mentioned cases the fragments were displaced more than half an inch downward.

Fig. 183.



Fracture of the coracoid process.

The symptoms are abnormal mobility and crepitation, but are not easily recognized, especially if the soft parts be much bruised and swollen; the depth at which the process is placed, and the thickness of the overlying muscles, make it difficult to grasp the process between the fingers or to appreciate its independent mobility. Gurlt recommends that the process should be grasped between the finger and thumb, one being placed under the clavicle and the other in the axilla, and that the scapula should then be moved with the other hand or by an assistant; crepitation may perhaps be recognized by this means, even if mobility is not. Malgaigne advises that the process be pressed downward in seeking for mobility. In a large proportion of the cases the injury has gone unrecognized because the attention of the surgeon has been confined to the more prominent associated injuries, especially when there was dislocation of the humerus.

The fracture in itself involves no danger to life, and no probable disability, although the union is seldom bony. Of six specimens examined by Gurlt bony union was found in only one; in four cases mentioned by him of which our knowledge is only clinical, mobility persisted in two. This failure of union does not seem to cause any loss of function. In Hulme's case mentioned above, the union was firm but the fragment somewhat displaced downward.

The treatment must be directed to immobilizing the arm in a position which will relax, as well as may be, the muscles attached to the process. Theoretically, the best position is that in which the forearm is flexed and the elbow carried across the front of the chest, but this cannot be carried

out thoroughly without causing more discomfort than the benefit to be obtained by it will warrant; and it is best, therefore, to simply fix the arm against the side with the forearm comfortably flexed. Hulme sought to keep the fragment in his case in place by putting a flat piece of cork below it and fastening it by means of a broad strip of adhesive plaster carried over the shoulder to the back.

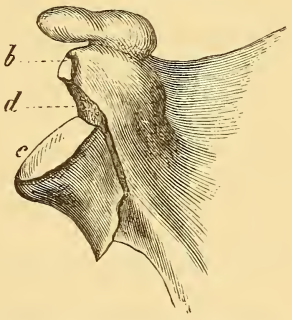
Fracture of the Surgical Neck of the Scapula.—This lesion, which was known to the earlier writers, and considered extremely dangerous by them, has received especial attention from some of the more prominent writers of the last century, most of whom, however, have grouped in one class fractures both of the neck and of the glenoid cavity. Gurlt described them separately, and the separation appears to be amply justified.

This author states that he has found in none of the museums of Europe a specimen of fracture of the anatomical neck of the scapula, that is, of the bone immediately behind the articular glenoid surface; and Hamilton says that he knows of no such specimen in America.

Under fractures of the surgical neck, Gurlt includes not only fractures which pass from the supra-scapular notch in a direction parallel to the surface of the glenoid cavity to the axillary border of the scapula, but also fractures which pass in front of the base of the coracoid process, or even through the upper part of the articular surface, and terminate below the attachment of the triceps. His second class—fractures of the glenoid cavity—have been found only in connection with dislocations, a portion of the articular rim being broken off.

In the variety now under consideration the fragment always carries with it the attachment of the triceps and usually the entire coracoid process; but the ligaments which bind the coracoid process to the clavicle and acromion remain untorn, as does also a ligament extending from the under surface of the spine of the scapula to the edge of the glenoid cavity, and they limit the displacement.

Fig. 184.



Fracture of the neck of the scapula. Spence's case. (Gurlt.)

The cases in which this fracture has been verified by dissection are five in number: the cases of Duverney, Neill, and Spence, a specimen in the museum of Guy's Hospital, and another in that of the Royal College of Surgeons at London. Gurlt describes the first three, and Flower[1] mentions the last two. Agnew[2] refers to two or three others, but does not say that they were verified by dissection. He also speaks, but without giving the reference, of a case of fracture by muscular action, "in the effort of placing a necklace over the shoulder." The exact character of Neill's[3] case is uncertain; in

[1] Holmes's System of Surgery, Am. ed., vol. i. p. 851.
[2] Loc. cit., p. 877.
[3] Am. Journal Med. Sci., new ser., vol. 36, 1858, p. 105.

Spence's[1] (fig. 184) the fracture passed in front of the coracoid process; in the others it appears to have passed through the supra-scapular notch.

The symptoms of the fracture are the flattening of the shoulder, the prominence of the acromion, the absence of the head of the humerus from the axilla (where it would be found if the injury were a dislocation), the easy reduction of the displacement by raising the elbow, its immediate return when the support is withdrawn from the elbow, and the crepitation which accompanies these movements. In two of Gurlt's cases the fragment could be felt in the axilla. The power of voluntary motion of the arm is lost, but passive movements are free, and, within certain limits, painless. On the other hand, manipulations which reduce the displacement or bring out crepitation cause much pain. Sometimes the lower edge of the fragment can be felt in the posterior and outer part of the axilla as a hard movable body which can be pushed upward, with pain and crepitation, but falls back as soon as the pressure is removed. In a case reported by Ashhurst,[2] crepitation was obtained by grasping the parts between the fingers on the shoulder and the thumb deep in the axilla and rotating the arm. There was very slight displacement. The patient was a boy five years old, and the fracture was caused by the fall of a shutter upon him.

The most characteristic symptom is the easy reduction and the immediate return of the displacement, and it is this which distinguishes it most sharply from dislocation of the humerus, the prominent symptoms of which are so similar.

According to Gurlt, bony union is the rule, fibrous union the exception, but in both cases with more or less displacement of the fragment and the humerus upward and downward. His collection contains only two cases of fibrous union; in one the patient had some use of the arm, in the other the limb was entirely useless. In the cases where bony union was secured, repair was complete in from four to seven weeks; in some there was slight diminution of the usefulness of the limb, but in the majority its use was fully regained.

It is doubtful if the parts can be supported by any dressing so perfectly that union without any displacement can be secured. The indications of treatment are to oppose the constant displacement inward and downward by raising the arm and carrying its upper end outward. Sir Astley Cooper sought to accomplish this by an axillary pad and a short sling for the arm; Gurlt recommends the same with the addition of a gutta-percha splint around the shoulder and a gypsum or dextrine spica.

Fracture of the Glenoid Cavity.—In all the instances that are on record, this fracture has been discovered *post mortem* after dislocation of the humerus. It is thought to be not uncommon, but, as the diagnosis is practically impossible during life, its frequency cannot be determined. Usually the fracture is of the inner border of the articular surface, but sometimes the outer or lower border has been broken off; and Flower[3] says that fractures have been found running across the

[1] Edinburgh Med. Journal, June, 1863, p. 1082.
[2] Trans. Coll. Physicians, Phila., 1875, 3d ser., vol. i. p. 69.
[3] Holmes's System of Surgery, Am. ed., vol. i. p. 851.

glenoid fossa and even splitting it up into several portions. Gurlt, on the contrary, says he has found no instance of general splintering, the fracture being limited, in all the cases of which he had knowledge, to the border. Agnew gives a figure of a stellate fracture, but does not state the source from which it was derived.

The symptoms cannot be described because no case appears to have been recognized during life; and it seems unlikely that a diagnosis could be made with any positiveness. The fragment is small and not accessible to direct manipulation, so that the only symptoms would be those of a dislocation together with crepitation on reduction, and, perhaps, a ready recurrence of the dislocation—signs that may be present under a variety of circumstances.

Treatment must be limited to reduction and immobilization, and the latter should be more complete and better guarded than after a simple dislocation, because of the greater ease with which the head of the humerus can escape from the glenoid cavity when the rim of the latter is broken.

CHAPTER XXI.

FRACTURES OF THE HUMERUS.

The tables in Chapter I. show that while fractures of the upper extremity (including the clavicle) constitute more than half of all fractures, those of the humerus are less than eight per cent. of all, and this bone is less frequently broken than either of the other portions of the limb; the percentages of the largest table are, forearm, 18.175; clavicle, 15.094; hand, 11.08; humerus, 7.863.

The following table made up by Gurlt from the statistics of the Berlin Hospitals shows the relative frequency in the different parts of the bone, periods of life, and sexes. It will be observed that it differs radically in some respects from the table in Chapter XIX. The most striking points in this table are the frequency of fracture during the first twenty years of life, and the preponderance of fractures of the lower end of the bone, especially during the same period:—

Age.	Upper end.		Shaft.		Lower end.		Total.	
	M.	F.	M.	F.	M.	F.	M.	F.
1 to 10 . . .	3	1	7	7	34	10	44	18
11 " 20 . . .	9	2	9	1	18	3	36	6
21 " 30 . . .	3	..	12	1	5	1	20	2
31 " 40 . . .	3	..	4	1	8	..	15	1
41 " 50 . . .	5	1	3	..	1	..	8	1
51 " 60 . . .	7	4	6	3	2	..	15	7
61 " 70 . . .	6	2	6	1	1	..	13	3
71 " 80 . . .	1	1	1	1	..	1	2	3
	37	11	47	15	69	15	153	41
	48		62		84		194	

The different varieties of fracture may be most conveniently studied by arranging them in three groups: fractures of the upper end, fractures of the shaft, and fractures of the lower end. The first and third groups severally contain varieties that differ materially from one another, but the classification is essentially a clinical one, and seems best suited to meet the needs of the practitioner who is called upon at the bedside to solve one of the most obscure and difficult of diagnostic problems, the character of a fracture in the vicinity of the shoulder or elbow joint, and who must carefully consider the bearing of the evidence, often scanty and indefinite, upon the contrasted possibilities.

For a remarkable case of longitudinal fracture extending the entire length of the bone that cannot be placed in any one of these groups the reader is referred to page 47.

1. Fractures of the Upper End of the Humerus.

In this group will be considered fractures of the head, of the anatomical neck, through the tuberosities, of the tuberosities, and of the surgical neck, and separation of the epiphysis.

By the *anatomical neck* is meant the narrow constricted groove lying just within the capsule at the edge of the articular cartilage; and by the *surgical neck* is meant the portion of the bone just below the tuberosities, between them and the insertions of the teres major and pectoralis major.

pathology and course.

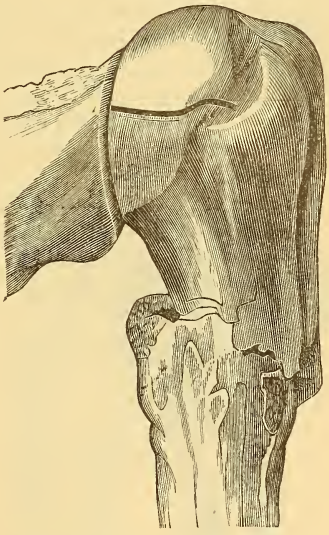
a. Fractures of the Head.—Simple fissures or partial fractures of the head of the humerus without associated fracture of the tuberosities or surgical neck are very rare. To the two instances which Gurlt quotes from Gosselin and Gross, may be added, I think, three others, one described by Malgaigne, the other two by Houel.

In Gosselin's case there were two fissures extending through the articular cartilage and for a distance of about one centimetre into the spongy bone. The cavity of the joint contained half an ounce of blood. Death was caused by delirium tremens fourteen hours after the accident, the nature of which is obscure.

Gross's case[1] is less demonstrative, being a specimen obtained several years after the injury. The fracture is described as having extended obliquely from above downwards through the head of the bone and as having become perfectly consolidated. It had been caused by a fall from a carriage.

Malgaigne's case[2] was an extensive fracture of the scapula, of the surgical neck and of the head of the humerus, the two latter not communicating with each other. The fracture of the head consisted of two fissures, one extending scarcely through the cartilage, the other to the depth of an inch into the spongy bone (fig. 185).

Fig. 185.



Fracture of the head of the humerus (Malgaigne.)

Houel's first case is a specimen in the Musée Dupuytren; about one-third of the head of the humerus has been broken off and has reunited.

His second case, also in the same museum, is a specimen of fracture through the head separating a thin fragment entirely covered with articular cartilage. The patient was an old woman and died seven or eight

[1] Gross's Surgery, fifth ed., vol. i. p. 985.
[2] Malgaigne's Atlas, Pl. 4, fig. 2. Text on p. 8.

months after the receipt of the injury. The fragment was turned completely over and not united. The specimen was given to the museum by Lenoir, who considered[1] it a fracture of the anatomical neck.

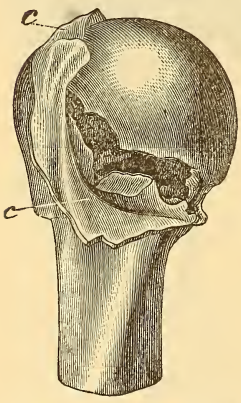
The cases are much more numerous in which the articular surface is fractured in connection with fracture of adjoining parts especially the tuberosities and the surgical neck. A beautiful specimen of fissure extending from the surgical neck up to and entirely across the head is in the Museum of Bellevue Hospital; it consists of the part above the fracture removed by operation. The history gives no details.

b. Fracture of the Anatomical Neck, and Fracture through the Tuberosities.—Pure fracture through the anatomical neck is a very rare accident, and the possibility even of its occurrence has been doubted by modern and recent writers, who are apparently not acquainted with the few fresh specimens in existence and who doubt the accepted interpretation of those in which union has taken place. Some of the specimens are described with a scantiness of detail that leaves the exact limits of the fracture somewhat uncertain and perhaps justifies the doubts just referred to, and in the descriptions of others the term *anatomical neck* is not used in the strict sense in which it is here employed; but there are a few specimens which seem to place the actual occurrence of this lesion beyond question.

Spence[2] presented to the Edinburgh Medico-Chirurgical Society a specimen of fracture of the anatomical neck of the humerus, the line of fracture lying between the head and the tuberosities entirely within the capsule. The injury was caused by a fall upon the shoulder, and the patient, who was an old man, died of apoplexy four weeks afterwards.

Boyer[3] reported a similar case; the patient was a woman 60 years old, and the fracture, which was caused by a fall upon the shoulder, occupied the sulcus between the head and the tuberosities. She died on the seventh day, apparently of tetanus, and the upper fragment was found to have been considerably reduced in size by absorption of its spongy tissue. I know of no illustration representing a specimen of pure fracture of the anatomical neck; figure 186 is the nearest.

Fig. 186.



Fracture of the anatomical neck of the humerus, with slight splintering and fracture of both tuberosities. (Gurlt.)

The examples of united or partly united fracture are less demonstrative, because it cannot be shown that the line of fracture followed the anatomical neck throughout; those that seem the least doubtful are reported by Sir Astley Cooper, Cloquet, and Gross.

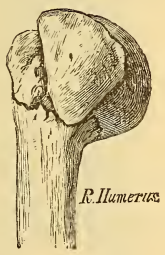
In most of the cases described by the authors as fractures of the anatomical neck the fracture has extended through one or both tuberosities, and usually the expanded end of the shaft has been splintered by impaction. In some cases the

[1] Gazette des Hôpitaux, 1858, p. 272.
[2] Edinburgh Med. Journal, vol. v., 1860. p. 1140.
[3] Traité des Maladies Chirurgicales, fourth ed., 1831, vol. iii. p. 199.

line of fracture follows the anatomical neck for a greater or less distance, and then diverges from it to (usually) the greater tuberosity, separating the bone into two principal pieces, the upper one of which is composed of the head and a small part of the adjoining bone, with little, if any splintering. In other and more numerous cases the upper portion of the bone is comminuted, or one fragment is impacted in the other. The mechanism in these latter cases is described as being (1st) fracture of the anatomical neck, and (2d) splitting off of the other portions by the wedge-like action of the separated head. Even if this theory could be proved, the clinical importance of the associated fracture of the tuberosities would still make it desirable, I think, that it should be recognized in the name, and, therefore, I prefer the term *fracture through the tuberosities*, reserving the other, *fracture through the anatomical neck*, for those rare cases in which the line of fracture is strictly limited to that portion. It is, perhaps, unnecessary to add that the differential diagnosis cannot always be made upon clinical data, and that practically we have to make only three groups: fractures of the anatomical neck with or without splitting of the tuberosities; fracture of either tuberosity; and fracture below the tuberosities, or of the surgical neck.

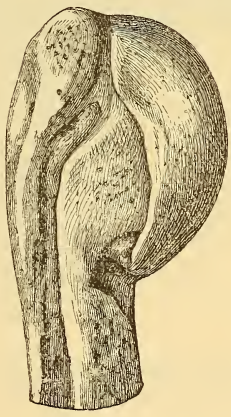
In these fractures through the tuberosities the fragments of the latter are generally held together more or less closely by the periosteum and the articular capsule, and the head itself is wedged in between them. If the impaction is close, consolidation may take place without further change in these relations, but it is not uncommon to see the articular fragment pushed inward and downward by the rising of the shaft, which is drawn up by the retraction of the deltoid. Mr. Jonathan Hutchinson[1]

Fig. 187.



Fracture of the neck and tuberosities of the humerus.

Fig. 188.



Fracture through the tuberosities of the humerus. Displacement downward of the head.

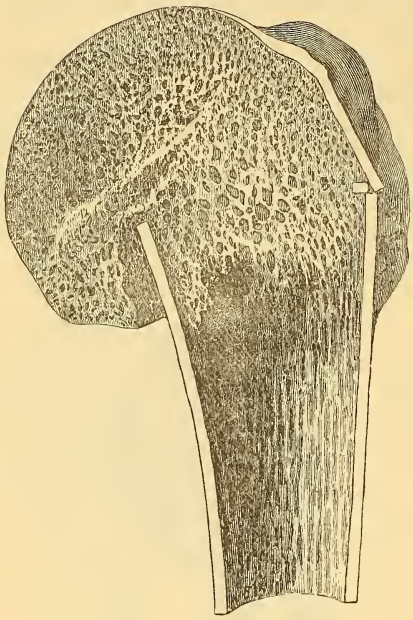
called particular attention to this late displacement and to the probability that if such a case were seen by any one for the first time, two

[1] Med. Times and Gazette, 1866, vol. i. p. 247.

or three months after the receipt of the injury, it would be mistaken for an unreduced dislocation. His own attention was called to it by observing a supposed dislocation at an autopsy; the history, given by the physician who had treated the case, was that of a fracture of the humerus a year before, while examination showed a fracture through the tuberosities and a descent of the head to a new articular facet just below the glenoid cavity. He says he has seen this condition often and has seen reduction attempted not infrequently.

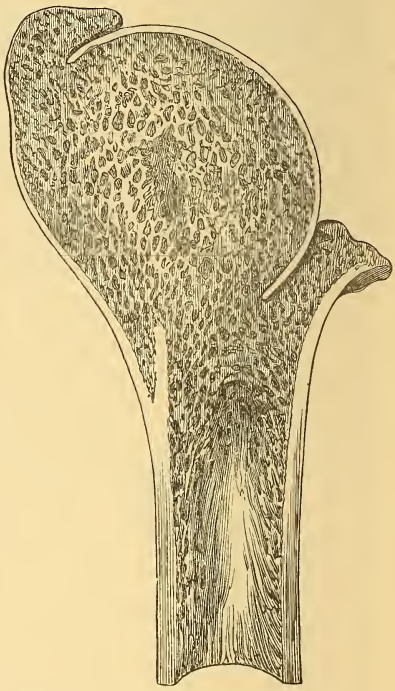
Instead of this gradual displacement downward the upper fragment is sometimes turned completely over so that its broken surface is directed towards the glenoid cavity and its cartilage is in contact with the broken surface of the diaphyseal fragment; or it may be driven bodily into the expanded end of the shaft, or it may be itself penetrated by the inner side of the shaft. The accompanying figures represent these different displacements as they appear after consolidation has taken place.

Fig. 189.



Impacted fracture of the humerus through the tuberosities. (R. W. Smith.)

Fig. 190.



Impaction of the head of the humerus into the shaft, with splitting off of the tuberosities. (R W. Smith.)

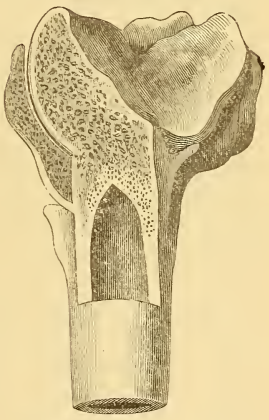
It has been maintained on theoretical grounds that in a pure intracapsular fracture or in one in which all the periosteal and capsular attachments of the upper fragment were entirely severed, this fragment would necessarily fail to unite, and that acting as a foreign body it would lead to suppuration within the joint and to its own ultimate elimi-

nation. Gurlt says there is no authentic instance on record in which this result has been effected, the supposed ones being in his opinion simply cases of suppurative disease of the bones forming the joint. It was shown in Chapter VI. that fragments of bone could preserve or regain their vitality after complete separation from the soft parts and even after transplantation to another animal, and we have, therefore, reason to believe that an intracapsular fragment may reunite if it remains in appropriate contact with the surface from which it has been broken. And, furthermore, even if union does not take place suppuration is certainly not inevitable; in Houel's second case, quoted above in the section on fractures of the head of the humerus, a fragment remained loose in the joint for seven or eight months without causing suppuration, and in others a similar fragment has remained fixed to the shaft by a peripheral callus or growth of osteophytes that imprisoned it but did not establish vital connections with it. In others, again, the fragment has undergone partial absorption.

Repair is carried on almost entirely by the distal portion of the bone and is marked by an exuberant production of callus and osteophytic growths on the surface and sometimes by ossification of the adjoining portion of the capsule of the joint.

Figure 190 represents a specimen described by R. W. Smith[1] in which, five years after the accident, "the head of the humerus was found to have been drawn into the cancellated tissue of the shaft between the tuberosities so deeply as to be below the summit of the greater tubercle; this process had been split off and displaced outwards; it formed an obtuse angle with the outer surface of the shaft of the bone. . . . Osseous union had taken place along the line of each fracture."

Fig. 191.



Fracture through the tuberosities of the humerus. Reversal of the head. (R. W. Smith.)

Figure 191 represents another specimen described by the same author of "impacted fracture of the neck of the humerus, accompanied by fracture of both tubercles." It was removed from the body of a woman 40 years old who had fallen down a flight of stairs many years before and had struck the shoulder violently against one of the steps. The appearances (at the time of death) were those of dislocation into the axilla, the acromion being prominent and the region of the deltoid flattened; but the arm was shortened, the glenoid cavity could not be felt, and the shaft of the humerus was drawn upward and inward so as to be almost in contact with the coracoid process; the motions of the joint were extremely limited and the scapular muscles atrophied. "The head of the bone was found to have been separated from the shaft by a fracture which traversed the anatomical neck of the humerus. It was

[1] Fractures in the Vicinity of Joints, 1854, p. 192.

reversed in the articulation, so that the fractured surface was directed upwards towards the glenoid cavity, and the cartilaginous articulating surface thrown downwards towards the shaft, and having assumed this position it was driven to a considerable distance into the cancellated structure between the tubercles. From this violent impaction of the head of the bone into the lower fragment a second fracture resulted which split off the lesser tubercle along with about two-thirds of the greater, and a small portion of the shaft of the humerus, corresponding to the upper part of the bicipital groove."

The entire cartilaginous surface of the head of the bone was not buried in the cancellated tissue of the shaft; its inner part was free, its outer part impacted to a depth of nearly an inch. The cartilage remained perfect, and was not united to the cancellated tissue of the tubercles and shaft. The remaining portion of the upper fragment, beyond the limits of the cartilage, was intimately and firmly united with the tissue of the tubercles; the reunion of the broken portions of the tubercles themselves was complete. A very similar case is reported by Krönlein in the *Deutsche Zeitschrift für Chirurgie*, 1874, p. 1.

c. Fractures of the Tuberosities.—Isolated fracture of either tuberosity is so rare an accident, except in connection with dislocation of the shoulder, that very few cases are on record, and none that have been verified by direct examination. Partial fracture of the greater tuberosity, that is, the fracture of a larger or smaller portion comprising some or all of the facets to which the supra-spinatus, infra-spinatus, and teres minor muscles are attached, is apparently a not infrequent accompaniment of dislocation of the humerus inward, and has also been seen by Malgaigne[1] in a case of dislocation backward under the acromion. Fracture of the lesser tuberosity is much more rare.

A number of cases have been reported of fracture of the greater tuberosity with symptoms so closely resembling those of dislocation, that the diagnosis of the latter lesion was at first made in each case. The first case was observed by Mayo, and published by Bransby Cooper,[2] as follows: "A gentleman, aged 60, in going up a flight of stairs fell, and in the attempt to recover himself fell again. When he was lifted up his left arm was useless and the shoulder in pain. On examining it within an hour after the accident, my first impression was that it was a dislocation of the shoulder. The acromion projected and the deltoid was flat below it. However, the elbow did not project from the side; and though motion of the shoulder was painful, yet it could be moved more easily than is usually the case in dislocation. The neck of the humerus was certainly not broken. When the arm was raised to a right angle with the scapula and pulled outwards from the elbow, the head of the bone seemed to be restored to its place. On lowering the elbow again the appearance of the shoulder was the same as at first. On carefully examining the outside of the head of the humerus I found the injury to consist in fracture and separation of the greater tubercle. . . . .

[1] Atlas, plate 22, figs. 5 and 6.

[2] Dislocations and Fractures, edited by Bransby Cooper, American edition, p. 378, Case 258.

The fracture united favorably; but for a long time the patient had some difficulty in carrying the arm backwards."

R. W. Smith[1] reported two additional cases, in one of which the nature of the injury was discovered at the post-mortem examination many years after it was received, and he was the first to call especial attention to the subject. He attributed its production to direct violence received upon the point of the shoulder and breaking off the tuberosity by direct action, and he attributed the displacement inward of the head to the action of the subscapular and of the anterior portion of the deltoid muscles no longer opposed by those attached to the greater tuberosity. Moreover, as the latter fragment is drawn upward and outward at the same time that the head is drawn inward the diameter of the shoulder appears to be much increased.

In both of Smith's cases the head of the humerus was below and somewhat on the inner side of the coracoid process, and the only reasons, apparently, for not calling it a dislocation were that the capsule was untorn in the one examined after death, that the elbow could be brought to the side, and that the deformity recurred easily. I do not think, however, that the simple separation of the tuberosity with its attached muscles would explain the occurrence of this displacement immediately after the accident; time would be required for the muscles to retract and to overcome the resistance of the capsule. It seems to me much more probable that the violence, which in both the cases observed clinically was severe—a fall down a staircase in one, and from the top of a three-story house in the other, caused a partial, perhaps, even a complete dislocation with separation of the tuberosity, and that the resultant laxity of the capsule and loss of support on the outer side were responsible for the easy recurrence of the displacement. The fact that the capsule was found untorn many years afterwards, is not a proof that dislocation had taken place. I observed a case of recent dislocation of the shoulder into the axilla, and showed the specimen to the New York Surgical Society, in November, 1880, in which the capsule was untorn; the symptoms were well marked and characteristic, and the upper facet of the greater tuberosity was broken off.

Gurlt quotes a case of supposed fracture of the tuberosity by muscular action, in which the symptoms were extreme passive mobility at the shoulder, complete loss of voluntary outward rotation, and partial loss of voluntary elevation of the arm. If the arm was rotated vigorously and the ear laid upon the patient's shoulder, crepitation could be heard. Four weeks later the corresponding muscles were still powerless and atrophied. The patient was a muscular youth of twenty years, and the lesion was produced by an effort to throw a snow-ball with force; something was heard to crack and the arm fell powerless. The only mention of displacement in the case is that the patient's brother, a physician, thought the arm was dislocated and "made a sort of reduction."

In April, 1881, I saw at the Presbyterian Hospital a youth of 19 years, who had been injured and admitted the preceding day. I copy the following notes from a record I made at the time. He said that

[1] Loc. cit., p. 176.

while holding the bridle of a horse in his right hand the animal reared, and as he came down his breast struck against the patient's left forearm which was held transversely before his face in protection, and threw him to the ground. The left shoulder was somewhat swollen, but presented no other deformity; there was an ecchymosis at the lower border of the tendon of the pectoralis major; crepitation high up in the shoulder obtained by grasping the head of the bone between the thumb and fingers and moving them; voluntary abduction possible; voluntary external rotation impossible; the weight of the body can be borne upon the elbow, the lesser tuberosity can be felt to move with the shaft when the arm is rotated, and there is pain on pressure over the greater tuberosity. I inserted an insect-pin in front over the bicipital groove; it passed straight backward its full length, evidently passing between two bony surfaces, and by pressing its point against the inner one and rotating the arm I determined the continuity of this surface with the shaft. My diagnosis was fracture of the greater tuberosity by muscular action, by outward rotation of the arm in the effort to ward off the descending body of the horse.

The man was discharged at his own request twelve days after the accident. Dr. Stickler, the house surgeon, examined him six months afterwards, and told me that he found the breadth of the shoulder a little greater, slight displacement of the tuberosity upward and outward, and a depression between the tubercle and the head of the bone in front more marked than on the other side. There seemed to be some diminution of the power of outward rotation. The patient complained of some "loss of power at the point of fracture" when lifting any considerable weight in the hand, or when pulling upon anything above and behind his head.

These two cases show that fracture of the outer tuberosity is not necessarily followed by displacement inwards of the head of the bone. The reason of the difference in the two sets of cases may lie in the persistence of some of the periosteal or tendinous attachments in the latter or in the simultaneous traumatic dislocation which I have suggested as possible in the former.

The following two cases taken from Gurlt's list of partial fractures are confirmatory to the extent of showing that the loss of the restraint of the supra- and infra-spinatus muscles alone does not lead to the displacement; and the direction of the teres minor is such that it can offer but little opposition to the contraction of the pectoralis major and anterior fibres of the deltoid.

1.[1] It was found by chance at an autopsy that the portion of the greater tuberosity to which the tendons of the supra- and infra-spinatus muscles were attached was broken off, a portion of the fragment remaining in the tendon, the rest having been absorbed. The tendon of the teres minor was in its normal position; that of the subscapularis partly, and that of the long head of the biceps completely, torn across. The cavity of the joint was uninjured, the clavicle was broken.

2. A man 46 years old dislocated his shoulder into the axilla by falling out of bed. Reduction was made by Mothe's method. Three months

[1] Dundas Key, in Lancet, 1844, ii. p. 198.

afterwards the patient died of apoplexy, having made use of the arm for some time. The portion of the greater tuberosity to which the supraspinatus was attached was found broken off.

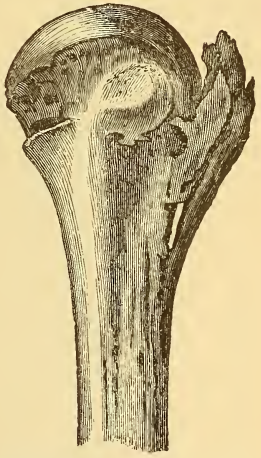
And in the two following cases of total separation no mention is made of displacement inward or of recurrence of the dislocation.

Malgaigne[1] treated a man 83 years old who had received an intracoracoid dislocation, and died exhausted on the tenth day. The greater tuberosity was torn off, broken into two pieces, and drawn back under the acromion. The tendon of the biceps had escaped from its torn sheath, and the capsule was separated on the inner side from the entire extent of the border of the glenoid cavity, was torn below and on the outer side, and was adherent to the humerus only at the insertion of the teres minor.

He quotes[2] also a case observed by Blandin, a man dying twenty-five days after the reduction of a dislocation forwards of the humerus with fracture of the greater tuberosity.

The line of fracture usually runs along the sulcus marking the anatomical neck at the part where it adjoins the tuberosity and down the bicipital groove, sometimes liberating the long tendon of the biceps from its sheath, and allowing it to slip in between the fractured surfaces. If the separation is complete the fragment is drawn upward and backward, if incomplete, that is, if the periosteum remains untorn on the side of the fragment adjoining the diaphysis, new bone fills up the lower part of the gap, and the upper part of the fragment stands out at a distance from the surface from which it has been torn, as in figure 192. When union takes place it is almost always bony.

Fig. 192.



Fracture of the greater tuberosity of the humerus united.

Fractures of the lesser tuberosity are extremely rare. Gurlt collected only three cases, two of them accompanying dislocation upward of the shoulder, the third a specimen in the pathological collection at Giessen without history. In each of the first two cases a small hard lump could be felt on the inner side of the head of the humerus, not moving with the movements of the arm. In one case it was excised three weeks after the accident, in the other the head of the humerus was excised after the dislocation had remained unreduced for three months.

d. Separation of the Epiphysis. — The upper epiphysis of the humerus comprises the head and the tuberosities. The epiphyseal line runs upward and outward along the lower and inner half of the anatomical neck and then transversely under the tuberosities to the outer edge, passing above the insertion of the teres minor. Its centre is higher than its edge, so that the shaft terminates above in a low cone or wedge, with, of course, a corresponding hollow on the under surface of the epiphysis. This cone

[1] Luxations, p. 513.

[2] Loc. cit., p. 57.

is very low in early life, and its height increases as the individual grows older, until ossification takes place, usually by the 20th year, but sometimes as late as the 25th. The subscapular, supra-spinatus and infra-spinatus muscles are attached to the epiphysis, so that this fracture is in many respects identical with fracture through the surgical neck.

This lesion has been observed at all ages between the moment of birth and the age of 19 years. In a considerable number of the recorded cases, it was produced by the efforts of the midwife or physician to hasten delivery by drawing upon the presenting arm, or with the finger hooked into the axilla, or to bring down the arm from the side of the head when the legs and body were already delivered. In young children it has been caused by falls, and by violently drawing the arm upward and outward; in the older cases it has been the result commonly of extreme violence, a fall from a height upon the shoulder, or having the arm caught in a revolving wheel.

The cases are not very numerous in which a direct examination has been made of the seat of fracture. Gurlt collected three cases in which the injury was caused during delivery, one each in children aged 4, 11, and 15 years, and a specimen obtained three years after the injury. In two of the first three the details are lacking; in the third the fracture appears to have followed the line of junction with the shaft very accurately; in one of the other three the fracture was compound, and the end of the diaphysis covered with a thin bluish layer of cartilage projected through the wound; in the remaining two there was some splintering, and the periosteum was torn from the diaphysis to a considerable extent, and remained attached to the epiphysis like a sleeve or fringe. In the last case the epiphysis had united with the neck of the scapula, and a new joint had formed at the line of fracture. In two of the cases it is mentioned that the capsule was torn.

The surfaces of fracture may preserve their relations to each other, or they may be separated from each other entirely, or in part. In one case the displacement was very slight, and appears to have been of the lower fragment backward, but usually the lower fragment is displaced forward for a distance equal to about half of its diameter, as pointed out by Dr. E. M. Moore,[1] and shown in fig. 193, and fixed in that position by the lodgment of its outer portion in the hollow of the head, which is inclined forward. When the transverse displacement is complete, the lower fragment is drawn upward and inward towards the coracoid process, and the upper fragment is rotated by the attached scapular muscles, so that its under surface looks forward and outward, or, in other words, so that the arm, if normally continuous with it, would be nearly horizontal, and the elbow directed forward and outward.

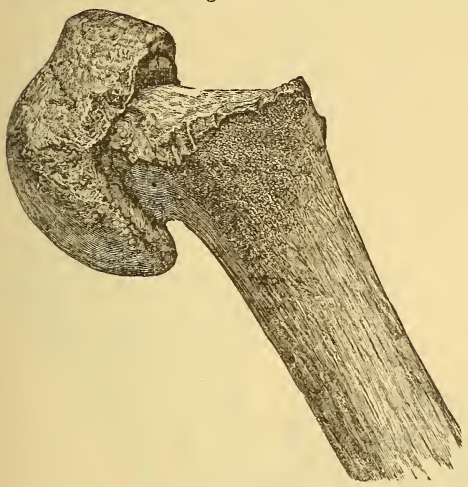
Figs. 194, 195, and 196 represent different views of the epiphyseal line.

The symptoms are quite characteristic when there is any displacement, and it seems improbable that any one who is at all familiar with them, even if in theory alone, would make the mistake that has been made occasionally of supposing the injury to be a dislocation.

[1] Transactions of Am. Med. Ass., vol. xxv., 1874, p. 296.

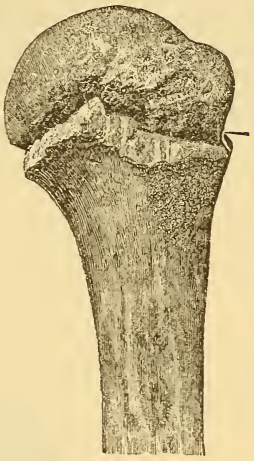
The arm hangs by the side, the elbow directed slightly backward and outward, and on the front of the shoulder, an inch or an inch and a half

Fig. 193.



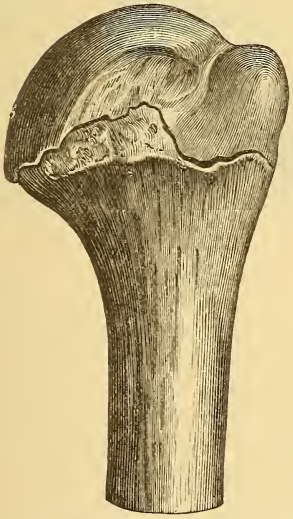
Separation of the upper epiphysis of the humerus; displacement forward of the lower fragment. (Moore.)

Fig. 194.



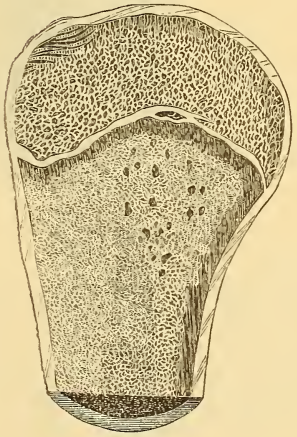
Upper epiphysis of the humerus at 10 years; separated by maceration. Outer side. (Moore.)

Fig. 195.



Upper epiphyseal line of the humerus; outer side. (R. W. Smith.)

Fig. 196.



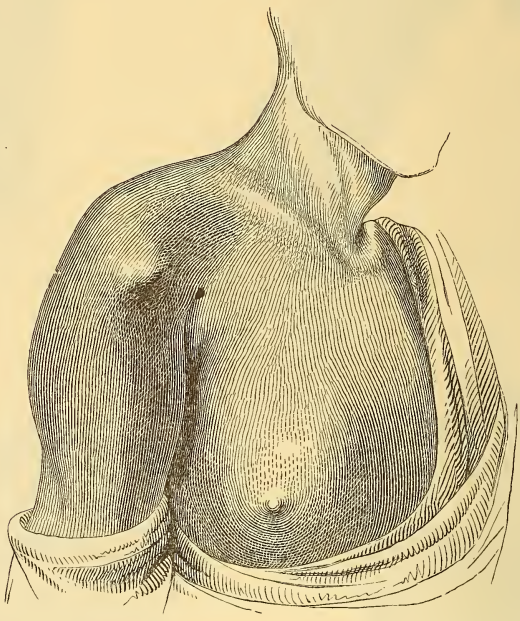
Section of the upper end of the humerus, showing the epiphyseal line.

below the acromion, is a distinct prominence that can be recognized by the eye or finger (fig. 197), the upper surface of which feels smooth and slightly convex; it moves when the elbow is rotated, and Dr. Moore

says that if at the same time the head of the humerus is tightly grasped between the thumb and fingers, crepitus can be perceived. In other cases the prominence is near the coracoid process, and crepitus is got by making extension, and then pressing the lower fragment outwards. Finally, there is the strong tendency of the displacement to recur.

The course of the affection is usually simple and favorable in this respect, that union is the rule with but little, if any, deformity, and no notable loss of function, for, even if the fragments unite at an angle, the range of motion is not interfered with appreciably. An unfavorable result may be due to failure of union (Hamilton reports such a case, a

Fig. 197.



Separation of the upper epiphysis of the humerus. (R. W. Smith.)

child thirteen months old), to suppuration at the seat of fracture, or to arrest of growth by premature ossification of the cartilage or by a complete transverse displacement with lateral union. See page 52 for cases of arrest of growth. Esmarch[1] reports a case of extensive osteomyelitis, with suppuration of the joint, in a child of 5 years, following a fall upon the shoulder which had caused a separation of the epiphysis; it was mistaken for, and treated as, a dislocation. He excised the head of the bone, and the upper end of the shaft, with a good result; that is, a useful limb, with but little shortening, and a free shoulder-joint. He does not say how long after the operation the observation of "slight shortening" was made, but probably it was not subsequent to the patient's dis-

[1] Langenbeck's Archiv, vol. xxi., 1878.

charge from the hospital, and the shortening doubtless became more marked as the patient grew older.

Fig. 198 represents a specimen, said by R. W. Smith to be an example of fracture along the epiphyseal line, united by bone, with marked displacement of the lower fragment inward.

Dr. Moore has been able to reduce the displacement easily by raising the elbow, and carrying it up as far as possible by the side of the head. As the upper fragment is already displaced in this direction, the posterior portion of the capsule, which is attached to it, is made tense before the elbow has been raised far, and arrests the further motion of the head; the continuation of the movement is then confined to the lower fragment, and brings it into its original relations with the upper one, after which the arm is lowered carefully and fixed. This is not required in all cases.

Fig. 198.

Union after separation of the upper epiphysis of the humerus with displacement. (R. W. Smith.)

e. Fracture of the Surgical Neck.— (Fig. 199.) This is by far the most common variety of fracture at the upper end of the

Fig. 199.

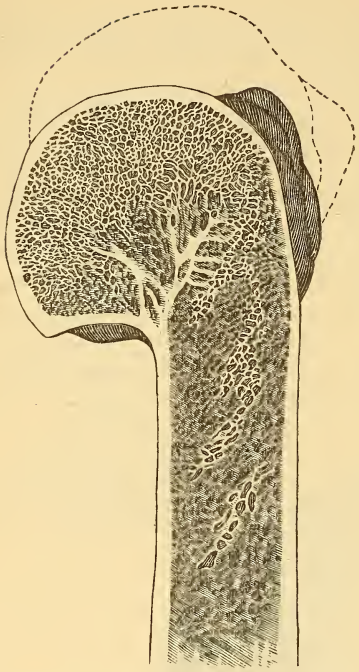
Fracture of the surgical neck of the humerus.

humerus; it occurs at all ages, and may be produced by direct violence received upon the shoulder, or indirectly by a fall upon the hand or elbow. The fracture may be transverse, oblique, or comminuted, but the line usually is quite irregular, and the fragments not infrequently impacted, and fissures may run up through the head of the bone into the joint, although the fracture is usually entirely extra-capsular. Esmarch[1] says that in young people fissures stop at the epiphyseal line, and that consequently in gunshot fractures of the shaft or surgical neck, it is not necessary to remove the head of the bone.

The displacements are various. The lower fragment may penetrate the upper one for half an inch or even more (fig. 200), the penetration being always most marked on the inner side and the head appearing in

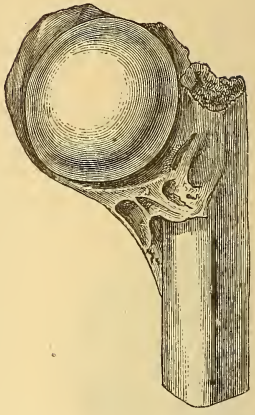
[1] Loc. cit.

Fig. 200.



Fracture of the neck of the humerus with impaction. (Malgaigne.)

Fig. 201.



Fracture of the surgical neck of the right humerus, seen from behind.

consequence to have slipped down the shaft. The upper fragment is acted upon by the scapula muscles in a manner that cannot well be opposed, and the consequence is that it is usually rotated outward and upward so that the surface of fracture looks forward or forward and outward and the lower fragment is drawn up past it on the inner side. Much more rarely the upper fragment is rotated inwards and forwards and the lower fragment lies on its outer side (fig. 201). The tendon of the long head of the biceps is liable to be torn in these extreme displacements, and in one reported case the pressure of the upper end of the lower fragment caused permanent occlusion of the axillary artery.

The oblique fractures show the same varieties of displacement, and in addition the sharp point of the lower fragment may perforate the soft parts to a greater or less extent, rendering reduction difficult or making the fracture compound. Occasionally, but very rarely, the deltoid is perforated by the end of the upper fragment.

In some cases there is no displacement, the periosteum remains untorn and the only symptoms are the swelling, the localized pain, crepitation, and more or less loss of function, but usually there is displacement of a kind and to a degree that make the diagnosis easy. The usual displacement of the upper end of the lower fragment inward is accompanied by the abduction of the elbow and a change in the direction of the long axis of the limb, similar to that found in dislocation, but the arm is at the same time shortened and movable and the upper fragment occupies the glenoid cavity, maintaining the roundness of the shoulder or perhaps exaggerating it by its own rotation outward. Incomplete perforation of the muscle or, especially, of the skin by the sharp end of the lower frag-

ment is recognized by the dimpling or drawing of the surface when the elbow is gently rotated. Crepitation and abnormal mobility are recognized by grasping the head of the bone between the thumb and fingers if possible, or by laying the palm of the hand upon the shoulder and then rotating the elbow and moving it in different directions. Steady extension should be made at the same time if there is reason to suspect an amount of overriding that would separate the surfaces. Ecchymosis, spreading often to a considerable distance over the chest and down the arm, is the rule, and sometimes the extravasated blood is sufficient in amount to lift up and distend the deltoid.

The course of the case depends very largely upon the severity of the injury, the extent of the fracture, and the complications that may exist or arise. If the displacement is slight or if it can be readily reduced the fracture will usually unite in the course of one and a half or two months without deformity or diminution of function, except, perhaps, in the old or rheumatic, in whom the joint may remain stiff for a long time. On the other hand, the displacement is sometimes irreducible and of such a character that after union has taken place the functions of the limb are found to be much interfered with by the irregular position of the fragments, or perhaps the joint is obliterated by the extension to it of the adjoining inflammation.

I have met with the reports of two cases in which the lower fragment was displaced upward and forward or upward and inward to a considerable height, and reduction could not be accomplished. The cases are those of Ledentu[1] and Lindner[2]. In the former case the patient was a lad 17 years old; there was shortening to the amount of two centimetres, and although the swelling was great the end of the lower fragment could be felt directly in front of the other. Elastic traction by India-rubber and adhesive plaster was begun on the sixth day and continued ten days, and then an immovable apparatus was applied until the twenty-fifth day. The swelling had then disappeared, the bicipital groove could be felt at the upper end of the lower fragment, and the shortening was only one centimetre. Traction by pulleys failing to remove this the surgeon tried to obtain a false joint, but in this also he was unsuccessful. Consolidation became complete during the third month and the movements of the limb were much restricted.

In Lindner's case the patient was 16 years old and came under observation on the thirteenth day after the injury. The lower fragment was displaced upward and inward toward the coracoid process, overriding the other for two inches or more. Attempts to reduce by traction failed, and as the movements of the limb were much restricted and the position of the fragments such that their union was improbable, Lindner cut down upon the bone on the twenty-third day and excised enough of the upper portion of the lower fragment to permit reduction. He found it so firmly adherent to the soft parts that he had much difficulty in removing it. The antiseptic method was used and the wound healed without incident, but at the date of the report, two months after the

[1] Bulletins de la Société de Chirurgie, 1876, p. 132.
[2] Centralblatt für Chirurgie, 1881, p. 225.

operation, the union of the bone was not solid. The limb, however, had become very useful and it was hoped that the union might yet become bony.

Mr. Hutchinson[1] mentions a case of fracture of the surgical neck well below the tuberosities in a lad of 10 years, in which the lower fragment was displaced upward behind the upper fragment and firmly fixed in this position "by the bands of detached periosteum through which it had escaped, and which prevented its being brought even on the post-mortem table into accurate apposition with the other fragment. For the same reason we had found it difficult during life to produce crepitus."

In a few entirely exceptional cases suppuration has taken place in simple fractures, apparently as the result of some complication such as erysipelas or septicæmia originating in another compound fracture or in severe bruising of the overlying soft parts.

The course of a compound fracture of the surgical neck is of course exposed to the interruptions common to that class of injuries, and in addition to the difficulties created by the thickness of the overlying soft parts and the proximity of the joint. The pus is likely to burrow down the arm and over the breast, and it is frequently necessary to remove a portion of the upper end of the lower fragment either because it has become necrosed or because its displacement cannot be overcome.

The result is usually a good one, so far as function is concerned, even if some displacement or shortening persists. The most that is to be looked for is a certain amount of stiffness in the joint persisting for a longer or shorter time in the old and arthritic. Union takes place in from five to eight weeks. Failure of union is rare.

Injury to the vessels or nerves seems to be almost unknown. There are a few recorded cases of rupture of or pressure upon the artery when the fracture was in the upper part of the shaft, but I have met with none where the fracture was plainly of the surgical neck. A case mentioned by Mr. Skey in the discussion on Syme's paper on axillary aneurism in the Med-Chirurgical Society[2] was probably one. "The patient, a woman, had suffered dislocation of the humerus, and eight or ten days after its reduction a large traumatic aneurism of the axilla presented itself. . . . The patient died and on examination it was found that there was a fracture of the neck of the humerus, the pointed end of the shaft having torn the artery across." The only case of injury to a nerve that I have met with is one treated in the service of Prof. Gosselin and reported by Berger.[3] The fracture was at the surgical neck, the lower fragment was displaced upward and inward and compressed the musculo-spiral nerve, causing loss of sensibility in the region supplied by it and paralysis of the muscles to which it is distributed. The patient died of scarlet fever, and the compression of the nerve was demonstrated by direct examination.

f. Intra- or Extra-Capsular Fractures with Dislocation of the Upper Fragment.—Dislocation of the upper fragment is a complication which

[1] Med. Times and Gazette, 1866, i. p. 248.

[2] Lancet, 1860, i. p. 445.

[3] Bulletins de la Société Anatomique, July, 1871; and Minier, Fractures de l'Extremité supérieure de l'Humerus, Thèse de Paris, 1879.

may coexist with fracture of the anatomical or surgical neck or fracture through the tuberosities. It is seldom, if ever, seen except in adults, and is the consequence of extreme violence usually acting directly upon the shoulder but sometimes through the elbow or hand. The mode of production cannot be positively known, that is, it cannot be determined whether the dislocation or the fracture is first produced, or whether they occur simultaneously. All three views have been maintained. I think it not improbable that in some of the cases the injury has at first been simply a dislocation, and that the fracture has been caused by the surgeon in his attempt to reduce it. One such case is reported by Richet;[1] in trying to reduce an old dislocation of the shoulder by traction and rotation he caused fracture of the surgical neck. The head was left under the clavicle, and the end of the shaft was brought back to the cavity of joint and fixed there. Six weeks later the patient could make some movements with the arm, and still later could use it almost as well as the other. Agnew[2] and Hamilton[3] have had a similar experience.

The fracture may follow the anatomical neck exactly or may diverge from it at any point and pass through the tuberosities, or may be entirely extra-capsular, and it may present any of the varieties in direction or comminution that have been previously mentioned in connection with the different fractures, and finally, it may be simple or compound. The dislocation is almost always into the axilla or under the coracoid process, occasionally backward under the spine of the scapula; the capsule is torn and the relations of the fragment with the shaft sometimes very much altered by the rotation of the former. In a case recorded by Malgaigne[4] the head of the bone was split into two pieces, the smaller of which remained in the cavity of the joint while the larger was displaced below and to the inner side of the coracoid process. The following two cases are quoted as illustrations of the rarer fracture in the recent state.

1.[5] A hemiplegic man between 60 and 70 years of age fell to the floor from his bed; he died on the 12th day. At the autopsy there was found a fracture of the anatomical neck of the humerus on the paralyzed side; the capsule was filled with synovia and partly coagulated blood, and the head of the bone had been displaced backward into the infra-spinous fossa through a rent in the posterior and outer part of the capsule, its articular surface was directed backward.

2. Malgaigne[6] quotes from Lallemand a case seen by the latter on the 38th day: the head of the bone, separated at the anatomical neck, was lodged under the clavicle opposite the upper border of the pectoralis minor and was covered by a false membrane which had already begun to resemble a synovial sac; the long tendon of the biceps was divided, the greater tuberosity torn off and broken in two, and the shaft of the bone, surmounted only by the lesser tuberosity, had been drawn up to a great height.

In the older cases of all kinds, those in which repair has taken place,

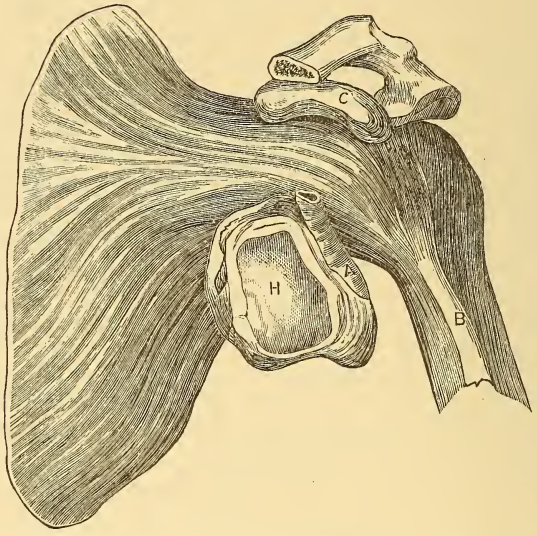
[1] Gazette des Hôpitaux, 1860, p. 159.
[2] Surgery, vol. ii. p. 65.
[3] Fractures and Disloc., 6th ed., p. 660.
[4] Luxations, p. 555.
[5] Delpech, Chir. Clinique de Montpellier, quoted by Malgaigne and Gurlt, p. 696.
[6] Luxations, p. 546.

the head is usually found atrophied, with its articular surface directed forward or downward, and immobilized by fibrous or bony bonds connecting it with the scapula, or reunited with the shaft and occupying an articular cavity of new formation. In other cases the shaft remains ununited, is drawn up into the articular cavity, and there forms a new joint with smooth surfaces, a capsule, and ligaments that are often quite free and useful. The following cases illustrate some of the various conditions found when the displacement has persisted for a long time.

1.[1] In the Museum of St. Thomas's Hospital is a specimen of dislocation of the head of the humerus and fracture at the anatomical neck caused some years before the death of the patient by a fall from a horse. The head of the bone lies on the front of the neck of the scapula immediately below the coracoid process and is firmly united to both.

2.[2] (Fig. 202.) Fracture at the anatomical neck, the head is in the

Fig. 202.



Fracture of the anatomical neck of the humerus, and dislocation of the head. *H*, the head; *C*, the coracoid process; *A*, axillary artery; *B*, tendon of the biceps.

axilla lying upon the subscapular muscle. The infra-spinatus and teres minor much wasted, the supra-spinatus and subscapular less so, the tendon of the biceps torn and adherent to the bicipital groove. The broken upper extremity of the humerus was lodged in the glenoid cavity, and had formed there a ligamentous joint. The head of the bone had a new capsular ligament to which the axillary artery adhered, it was on the sternal side of and a little below the level of the coracoid, it was united to the humerus by a small process of bone but not to the scapula.

[1] Transactions Path. Soc., of London, 1861 (vol. xii.), p. 198, Case 36.
[2] Sir Astley Cooper in Guy's Hosp. Rep., 1839, vol. iv. p. 275.

3.[1] The injury was received several years before the death of the patient. The head of the humerus was dislocated into the axilla and broken from the shaft, and it remained upon the inner side of the inferior costa of the scapula, to which it was firmly united. The tuberosities were broken off with the head, and the fractured extremity (lower) of the neck was placed in the glenoid cavity of the scapula. The underhand motions of the shoulder were restored, but the elevation of the bone beyond a right angle was strongly resisted, and even with difficulty could be accomplished in the dead body.

4. A woman[2] 83 years old fell to the ground while walking. There was considerable swelling of the upper part of the arm, ecchymosis, shortening to the extent of two centimetres, crepitation. The diagnosis of fracture of the surgical neck of the humerus was made, and the limb was kept in splints until her death, more than three months afterwards, at which time there was apparent union. At the autopsy the head was found separated at the anatomical neck, resting against the third rib, and connected with the cavity of the joint only by a small piece of the capsule; it was rotated so that its articular surface looked forward, and it lifted and was covered by the brachial nerves and the artery. There was also a fracture of the surgical neck that had united without deformity. The upper end of the humerus was bound to the glenoid cavity by broad short bands passing from its broken surface.

The symptoms are in part those of dislocation, in part those of fracture. The shoulder is more or less flattened, the acromion prominent, and the head of the bone to be felt in the axilla, but the elbow does not stand out from the side as it does in a dislocation, the arm hangs down and the hand can be placed on the opposite shoulder. The limb is usually shortened, although at first it may be lengthened by the weight of the arm overcoming the bruised and partly paralyzed muscles, and then it can be lifted directly up so that its upper end occupies the cavity of the joint and fills out the shoulder again. Crepitation can generally be felt when the lesion is fresh, either by simple rotation or by combining it with traction. In an old case which I saw in consultation and which was supposed to be a simple dislocation, and in which vigorous attempts to reduce under ether had been made a few days before, it could be plainly seen that the axis of the limb did not run toward the round hard lump (apparently the head) which lay under the pectoral muscle, but toward a point on its outer side, the head did not share in movements communicated to the elbow, and crepitation could be perceived. It was thought that the efforts to reduce the dislocation had produced a secondary fracture.

A man between 60 and 70 years of age fell from a loft to the floor in a barn, striking with his left shoulder on the floor and against a beam on the way. The shoulder was markedly flattened behind, and the region of the pectoral muscles showed a rounded prominence. The elbow stood out from the side and was directed backward. The raising of the arm showed an unusual and very painful mobility not shared by the head of

[1] Idem, p. 274.
[2] Gaz. des Hôpitaux, 1851, p. 29; and Malgaigne, Luxations, p. 547.

the bone which could be felt plainly under the pectoralis major. The somewhat shortened arm could be lengthened by traction, and crepitation could be perceived.

Reduction was accomplished by having an assistant draw the arm horizontally from the body while the surgeon pressed the freely movable head toward the joint with his thumbs. The patient was careless and disobedient, and the displacement recurred on the second, and again on the sixth day, it was easily reduced each time and then the arm was kept in pasteboard splints for six weeks. The usefulness of the limb was completely restored.

Malgaigne[1] saw a case which terminated in suppuration and death in two months. The patient was feeble-minded and could give no account of the manner in which the injury was received. It was thought to be a dislocation and attempts to reduce it were made. An abscess formed, and Malgaigne saw the patient two weeks before death: the presence of the head of the bone under the clavicle, the shortening, and the mobility indicated plainly a fracture of the surgical neck, but the shallowness of the subacromial depression made him think that a portion of the head still remained in the cavity of the joint. The autopsy showed a fracture of the anatomical neck with a comminution that included the surgical neck; the fragments were united by an exuberant callus and occupied the greater part of the glenoid cavity. The two tuberosities had disappeared, and the tendons which are attached to them were ossified. The head, greatly hypertrophied, was covered with prominent irregular layers of bone, a fibrous band had united with its broken surface, and another with its summit.

In another case[2] a man 45 years old fell from his bed upon his right shoulder. Dislocation was recognized, extension made by three assistants, and rest in bed ordered. Eleven months afterwards the patient consulted Malgaigne, the shoulder was flattened but the fingers pressed under the acromion recognized a bony prominence covering the glenoid cavity and continuous with the shaft of the humerus. Behind, half an inch below the posterior angle of the acromion, could be felt a semiglobular prominence about two inches in diameter which seemed to be immovably attached to the edge of the glenoid cavity, and was evidently the head of the humerus. The upper end of the shaft was in the glenoid cavity and slightly movable upon it. The arm was shortened half an inch, the elbow barely separated from the body and without rotation. All attempts to increase the range of motion at the shoulder failed.

A man[3] 22 years old was kicked upon the shoulder by a horse, and when seen by the surgeon four weeks afterwards had been unable to use the arm on account of the pain and swelling. Examination showed a dislocation of the humerus under the coracoid process with crepitation and mobility that indicated probable fracture at the anatomical neck. A gutta percha splint was applied, and sixteen weeks later an attempt was made to reduce the dislocation, but without success, and crepitation was again perceived. A second attempt made a fortnight later was also

[1] Luxations, p. 546.
[2] Malgaigne, Luxations, p. 548.
[3] Gurit, loc. cit., p. 736, Case 175.

unsuccessful. The patient could raise the arm to the horizontal position and the muscles were not atrophied.

A[1] man 20 years old while trying to restrain a horse was thrown down and dragged a short distance and received a compound fracture of the neck of the humerus, the shaft projecting in the axilla, and the skin and muscles on the anterior portion of the limb much lacerated. Reduction was accomplished by raising the arm to the horizontal line and then bringing it down, but the upper end of the shaft lodged below the clavicle, where the head of the bone also was, and could not be removed. The wound healed with suppuration, down to a few sinuses through which several splinters were discharged during the following six months. Two years later the patient returned to have the sinuses closed. The cavity of the joint was empty, the head of the humerus lay under the clavicle and behind the pectoralis major and was necrosed, after its removal the sinuses healed. Mobility was good, but elevation was defective.

Diagnosis.—It is sometimes extremely difficult to determine on examination of a recently injured shoulder whether or not fracture has taken place, and after the diagnosis of fracture has been made the recognition of the variety may be even more difficult, although perhaps practically less important. In any case of injury to the shoulder of doubtful nature the surgeon's first effort should be to determine whether or not the head of the humerus is in its proper place, and he will do this by observing the direction of the long axis of the shaft and by feeling for the head under the acromion. If the head is found in place its continuity or lack of continuity with the shaft is determined by grasping it between the thumb and fingers and rotating the elbow gently with the other hand, or by grasping the head with both hands while an assistant moves the elbow. If the head does not share in the movements there must be a fracture, but the converse is not equally true, for in an impacted fracture the movements of the lower fragment will be communicated to the upper one. By the manœuvre crepitation may be produced. In doubtful cases where the connections or the independent mobility of certain parts cannot be determined by the hands alone, it may be proper to use acupuncture needles. The shape of the shoulder must be carefully examined, the direction of the axis of the arm, and its relations to the supposed head of the bone noted, and the degree of mobility of the limb and its shortening or elongation. Pain, ecchymosis, and swelling are common to most injuries, but sometimes gain a diagnostic value from their position.

The question to be first settled in a case of injury is whether it is a fracture, a dislocation, or a simple contusion, and in order to avoid the frequent repetitions that would otherwise be necessary I give briefly under the head of each injury which may be in question the signs and symptoms by which its diagnosis may be made.

Dislocation (inward and downward).—Rare in children, frequent in adults. Shoulder flattened, acromion prominent, outer fibres of the deltoid straight and tense. Elbow abducted, arm rotated inward. Head of the humerus in the axilla or behind the pectoral muscle and con-

[1] Gurlt, p. 736, Case 176.

tinuous with the shaft, its absence from below the acromion recognizable by the depth to which the finger can be pressed. Active movements at the shoulder lost, passive movements greatly diminished, elbow cannot be brought in front of the body nor the hand placed on the opposite shoulder. Deformity does not reappear after reduction. Arm lengthened in the subglenoid, and shortened in the infra-clavicular dislocation.

Fracture of the Neck of the Scapula.—Very rare. Arm dependent and slightly lengthened, elbow slightly abducted, shoulder flattened, acromion prominent, possibly some fulness in the axilla. Deformity easily overcome by pushing the arm up towards the acromion but returns as soon as the arm is left unsupported; crepitation felt during this manœuvre. Active movements impossible, passive movements free.

Fracture of the Head of the Humerus.—Extremely rare, usually a complication of fracture of the surgical neck. No displacement or deformity. Movements not greatly interfered with, crepitation possible, diagnosis very obscure.

Fracture of the Anatomical Neck.—Advanced age; uncommon; position and length of arm natural, shoulder unchanged or somewhat flattened, head of the bone may perhaps be felt in the axilla; crepitation may be either present or absent; possibly recognizable enlargement of the upper end of the bone by the splitting off of the tuberosities. Movements usually free.

Fracture of the Greater Tuberosity.—Rare except as a complication of dislocation. Position of the arm natural; upper end of the bone feels enlarged, and a sulcus can be felt between the tuberosities in front; crepitation; movements free, active outward rotation lost.

Separation of the Epiphysis.—Uncommon; unknown after 18 years of age. The arm is directed downward, backward, and outward, but the elbow can be easily brought to the side; the upper end of the shaft projects in front or on the inner side of the head which can be felt in its normal position and does not move with the shaft. Crepitation when reduction is made; reduction sometimes very difficult. In other cases there is no displacement, and the only signs are localized pain at the epiphyseal line, loss of active movements, possibly crepitation and abnormal mobility.

Fracture of the Surgical Neck.—Very common, especially in elderly people. May be impacted; in the young is likely to be oblique with projection of lower fragment. The symptoms are very variable; the arm is usually shortened and the elbow somewhat abducted; the upper fragment usually lies on the outer side of the lower one and is rotated so that its broken surface is directed outward or outward and forward; the lower fragment may penetrate or completely perforate the muscles and skin on the inner side of the arm. Palpation shows the presence of the head in the joint, its separation from the shaft, and crepitation. In impacted fracture the displacement is much less and crepitation is slight or absent. In exceptional cases the upper fragment may lie on the inner or posterior side of the lower one. Voluntary movements lost, passive movements usually free but painful. Reduction difficult or impossible.

Fracture with Dislocation of Upper Fragment.—Infrequent and almost confined to middle or advanced life. Arm dependent and usually

shortened; region of the shoulder presents the signs of dislocation; upper end of lower fragment in or near the cavity of the joint; upper fragment can be felt in the axilla or under the coracoid process or clavicle, is usually movable and does not move with the shaft, crepitation. The arm is freely movable, passively, in all directions; reduction difficult.

For gradual displacement resembling an unreduced dislocation see section on fractures of the anatomical neck (p. 358).

Treatment.—After fracture of the head or of the anatomical neck with or without splitting off of the tuberosities there is rarely anything to be done by way of reduction, and the treatment is limited to moderate fixation and local antiphlogistic measures. In view of the tendency of the head to be crowded to the inner side by the retraction of the deltoid and the consequent rising of the shaft, the elbow should be left partly unsupported in order that the weight of the arm may be utilized as an extending force to oppose the retraction of the muscles. With this object the supporting sling should be placed under the forearm near the wrist.

If the upper fragment acts as a foreign body and provokes suppuration within the joint it must be removed by operation, and if the adjoining surface has become carious a formal excision will probably be required.

After avulsion of the greater tuberosity, the displacement cannot be overcome by opposing the contraction of the muscles which draw the fragment away, because the latter is far too small and too deeply placed to permit efficient control over it, and the only means of bringing the two broken surfaces together again is to abduct the arm to an extent corresponding to the displacement of the fragment; and in order to prevent recurrence the arm must be maintained in this position until union has taken place. In the simpler cases, apparently, enough of the periosteum remains untorn to keep the fragments from separating widely, and the disability that follows fibrous union with some separation is not enough to justify the discomforts of the restraint which the abducted position of the arm would entail. In the case mentioned above which came under my own observation the only treatment was rest with as much outward rotation of the arm as could be conveniently maintained by the patient himself, and the resultant disability was very slight.

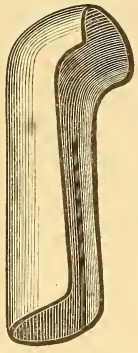
In the graver cases, such as those quoted from R. W. Smith, where the head of the bone tends to move toward the chest as in a dislocation, the tendency must be opposed by some restraining dressing, such as a pad in the axilla, or a combination of splints such as are used after fracture of the surgical neck, or by fixation of the arm as after dislocation with frequent examinations of its position during the first few days or until the tendency to displacement has disappeared.

After fracture of the surgical neck or separation of epiphysis, in which the mechanism of displacement is the same, the indications for reduction are to overcome the overriding, if it exists, and the angular displacement due to the abduction of the upper fragment. Mention has been made of the method suggested by Dr. Moore for reduction after separation of the epiphysis, the method which consisted in making use of the posterior portion of the capsule to hold the upper fragment still while the lower one was brought into line with it by forced elevation of

the elbow. The principle of the method is one that has often been made use of under other circumstances and is the basis of a method of reduction after fracture of the surgical neck, viz., abduction of the arm to bring the fragment into line, followed, when necessary, by extension and coaptation. After reduction has been thus accomplished the arm must be lowered carefully to the body and secured with splints. In a few cases it has been found impossible to maintain the reduction except by keeping the arm abducted. In transverse or toothed fractures the retention is not difficult, especially if the fragments can be interlocked or slightly impacted, but in oblique fractures with the line of fracture running downward and outward, as is common in young adults, there is nothing to oppose the constant tendency of the outer scapular muscles to abduct the fragment to which they are attached.

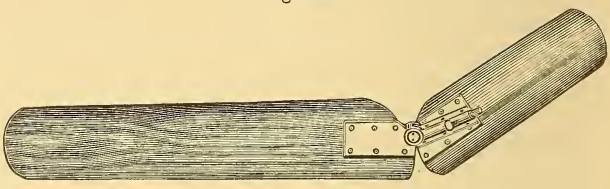
The dressing in common use is a combination of lateral splints and a shoulder cap. The outer splint is a moulded one made of leather, pasteboard, gutta percha, or plaster of Paris, to fit the outer half of the arm and shoulder, from two inches above the acromion to the outer condyle of the humerus (fig. 203). The inner splint may be a short moulded one extending from the axilla to the elbow, or a long, angular, wooden one reaching to the wrist (fig. 204). The splints are applied either directly upon the surface, or, preferably, with an interposed layer of sheet lint or a compress, and bound fast with a roller bandage applied from below upwards, and ending in a sort of spica at the shoulder. It

Fig. 203.



Moulded splint to fit the shoulder and arm.

Fig. 204.



Angular internal splint.

is not necessary that the inner splint should rise high in the axilla; it is intended not to act directly upon the upper fragment, but only upon the lower one, aiding in maintaining its relations to the outer splint. The object of the splint is to keep the upper end of the lower fragment from being displaced inward; it is practically powerless to prevent shortening or the outward rotation of the upper fragment, except by keeping the surfaces of a transverse or toothed fracture in contact. The outer splint is the effective one, because it finds a fixed point at the acromion, which enables it to oppose displacement inward

If the shoulder is much swollen at first, the application of a moulded splint should be deferred, for the alteration in the shape of the limb, effected by the subsidence of the swelling, would spoil the fit and increase the chances of displacement. Under such circumstances it is better to keep the patient in bed, apply soothing lotions, and immobilize the limb meanwhile by bandages, cushions, or extension.

If there is a marked tendency to overriding, to a projection of the sharp point of the lower fragment, it must be met not by additional bandages passing under the axilla and over the top of the outer splint, or by lengthening the inner splint upward and filling the axilla with a pad, but by making continuous extension upon the limb with adhesive plaster and a weight and pulley, or an elastic cord. The extension should be made towards the foot of the bed at an angle of from 30° to 45° with the long axis of the body, and the arm should be supported upon cushions or sand-bags. Counter-extension, if necessary, is made by a cord, one end of which is fastened to the head of the bed, and the other to strips of adhesive plaster on the breast and back.

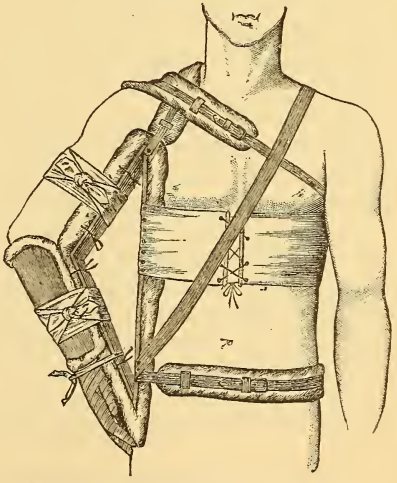
When the patient is allowed to walk about, the forearm should be supported across the chest by a scarf or sling passing under the wrist, and leaving the elbow unsupported in order that its weight may make extension. It may sometimes be desirable to increase this extension by suspending a weight from the elbow. I have done this with advantage in fractures of the shaft.

Some surgeons advise that the hand and forearm should be bandaged to prevent swelling, others think it entirely unnecessary. The need seems to vary with the different cases.

Erichsen recommends, as a very convenient dressing, a leather splint about two feet long and six inches broad, bent upon itself in the middle, so that one-half rests against the side of the chest, and the other half against the inside of the injured arm; the angle formed by the band should be rounded and pressed well up into the axilla. This may be a useful addition to the outer splint, but I do not consider it advisable to oppose displacement inwards by direct pressure upon the projecting fragment.

When the upper fragment is rotated outward and abducted, and cannot be brought back into line, the arm must be fixed in the abducted position which corresponds to that of the upper fragment. A rectangular splint has been used successfully in such cases, one portion resting against the side of the chest, the other supporting the arm. Middeldorpf's triangle (fig. 205), which fixes the arm in a position of partial abduction, is recommended by the German surgeons.

Fig. 205.



Middledorpf's triangle for fracture of the humerus.

In compound fracture with opening of the joint (usually gunshot), loose fragments should be removed, and primary excision of the joint is to be preferred to disarticulation, if the main vessels and nerves are uninjured. Conservative treatment should be tried at first if the injury is not very severe, but it must be borne in mind that secondary excision will probably become neces-

sary. The subperiosteal method should be used, and the surgeon's aim should be to obtain a movable joint. Passive motion should be begun after excision as soon as the wound has ceased to be sensitive, and suppuration is well established. Particular attention should be paid from the first to preventing stiffness of the fingers and wrist, by encouraging the patient to move them frequently. Immobilization should be sought at first by pads and cushions, or by a plaster dressing if possible; a pad in the axilla and one behind the upper part of the arm will prove useful.

Compound fractures not involving the joint are to be treated on the same principles as fractures of the shaft of the bone. Their especial possible complication is extension of the inflammation to the shoulder-joint with all its important, immediate, and remote consequences.

In fractures complicated by dislocation of the upper fragment the indication is to reduce the dislocation under ether at once, if possible. There are a number of cases on record in which this has been done successfully by placing the thumb against the head of the bone and the fingers upon the outer border of the acromion, and forcing the former back into place. The complete muscular relaxation of anæsthesia is very useful and may be absolutely necessary in this reduction, for although the desired end has been attained without it, the failures were so numerous formerly that the older writers usually spoke of the displacement as irreducible. The arm should be held in the horizontal abducted position during the attempt, and gentle traction may be made upon it at the same time, in order that it may accompany the head in its change of place. This attempt should be made in every case as soon as the exact condition of the parts is ascertained, as soon, that is, as it becomes known that the injury is a fracture with dislocation. No time should be lost in waiting for the swelling and inflammation to subside, and, on the other hand, the effort should not be unduly prolonged.

If the attempt fails there still remains the choice between trying to reduce the dislocation after the fracture has consolidated, and seeking to get a useful false joint at the seat of fracture. The recorded examples of the former are neither numerous nor encouraging, failure appears to have been the rule, death was caused once, and in two cases the effort was successful. One of these two was reported by Warren, of Boston, the other was treated in Von Langenbeck's clinic at Berlin.

In Warren's case[1] the patient was a young man, and an attempt to reduce the dislocation immediately after the accident that had caused it failed. Consolidation took place in four weeks, the attempt was then renewed and was successful in half an hour.

In Von Langenbeck's case[2] the patient was 42 years old, and had broken his humerus by falling from a chair four weeks before he was admitted to the hospital. At this time the arm was abducted, the shoulder flattened, the acromion prominent, and the head of the humerus could be felt under the pectoral muscle. The diagnosis of dislocation was made, and the coexistence of a fracture discovered only during an attempt at reduction. The limb was then placed in splints, and eleven weeks afterwards the attempt was renewed with success.

[1] Boston Med. and Surg. Journal, 1828, vol. i. p. 12.
[2] Gurlt, loc. cit., vol. ii. p. 735, Case 172.

The fatal case[1] was also in Von Langenbeck's clinic. A sailor, 17 years old, was thrown against the side of the vessel during a storm, and injured his shoulder so that he was unable to use his arm. Three weeks afterwards he sought treatment in England; the injury was supposed to be a dislocation and eight attempts to reduce it were made in two different hospitals, with the aid of chloroform and pulleys. Eight weeks after the accident he was admitted to Von Langenbeck's wards; the shoulder was flattened, the acromion prominent, the head of the humerus to be felt through the axilla under the coracoid process; the arm was slightly abducted, movements limited and painful.

Three unsuccessful attempts to reduce the dislocation were made in ten days, and were followed by high fever, occasional delirium, and great swelling of the arm; an incision which let out a quantity of thick, tarry blood was made just below the joint, and the patient died seventeen days after admission. The autopsy showed fracture along the epiphyseal line and separation of the greater tuberosity; the lesser tuberosity had disappeared by absorption, and osteophytes had formed upon the shaft and the greater tuberosity. The fragments occupied a large cavity extending from the clavicle to the axilla and filled with coagulated blood, which had escaped into it from the torn cephalic vein.

The remaining alternative, that of seeking to create a useful false joint at the seat of fracture, may be adopted after the other attempts have failed, or early in the progress of the case if there seems no reasonable prospect of getting the head of the bone back into its cavity. The following case observed and reported by Sir Astley Cooper[2] shows how useful such a joint may be.

A man was thrown from a horse and received an injury of his shoulder which was thought to be a dislocation and was reduced. Five weeks afterwards Sir Astley Cooper found the head of the humerus in the axilla. The arm was useful for all purposes to which the dependent position was suitable, but could not be raised either actively or passively because of pain. Its mobility became much increased afterwards. At the autopsy many years later the head was found behind the coracoid process firmly united to the inner surface of the scapula, while the shaft of the bone with the attached tubercles occupied the cavity of the joint.

In a case quoted by Gurlt[3] the condition of the parts several weeks after fracture of the neck of the humerus with dislocation was such (failure of union and irritation of the soft parts) that the surgeon exposed and removed a considerable portion of the upper end of the lower fragment. The arm became very useful.

Excision of the upper end of the lower fragment has also been done in a few cases of vicious union, for the relief of pain and increase of the movements of the arm; and in one case of fracture with overlooked dislocation, the head of the bone was removed a year or two after the accident and a good result obtained. In another, reported by Vogt,[4] a

[1] Gurlt, loc. cit., vol. ii. p. 698, Case 101.
[2] Guy's Hospital Reports, 1839, p. 273, Case 1.
[3] Loc. cit., vol. ii. p. 731, Case 156.
[4] Deutsche Zeitschrift für Chirurgie, vol. vii., 1876–7, p. 152.

girl 11 years old had lost the use of and sensation in the arm in consequence of a fracture of the surgical neck of the humerus resulting in pseudarthrosis and large callus. He excised the upper part of the humerus, but the restoration of function was imperfect.

It may be reasonably expected, it seems, that the usefulness of the limb under these circumstances will increase with time, but it appears desirable theoretically that the decision to try for a false joint should be reached as promptly as possible, before firm union shall have taken place between the fragments, and in order to bring the lower fragment as nearly as possible into the cavity of the joint.

2. Fractures of the Shaft of the Humerus.

All the varieties of fracture which may occur in long bones are contained among those of the shaft of the humerus. A remarkable and unique example of longitudinal fracture extending the entire length of the bone was quoted in Chapter II. (p. 47), and Gurlt gives two of exceptionally long fissures, beginning in the one case at the condyles and ending at the insertion of the deltoid, and extending in the other from the upper border of the greater tuberosity to the lower fourth of the shaft. Incomplete or partial fractures are extremely rare.

Fig. 206.

Fissure of the humerus. (Gurlt.)

All the forms of displacement common to fractures of long bones are also found here, and no one deserves mention as of exceptional occurrence and importance. The character of the displacement seems to depend largely upon the fracturing force, and much less upon the contractions of the muscles than has been asserted by some writers. Malgaigne asserts that the displacement in fractures caused by muscular action is slight, and the statement has been accepted and repeated by subsequent writers.

Double fractures of the same bone are very rare ; mention has been made in Chapter II. of one reported by Sir Astley Cooper, and another is described and pictured in Malgaigne's Atlas, Plates VI. and VII. Simultaneous fracture of both humeri has been caused in one case by epileptic convulsions, and in others by external violence. Gurlt quotes a case from Mauquest de la Motte who saw in 1689 a boy 9 or 10 years old who had broken both his arms in playing with another boy, the left one above the elbow, the right one three or four finger breadths below its head. He was watched constantly by two maidservants, alternating with each other, and recovered in three weeks without a trace of displacement or deformity. In the Museum of Bellevue Hospital, N. Y., there is a specimen of partly united double or treble fracture taken from the body of a woman whose bones had become so friable during the few months preceding her death that they broke under the slightest causes.

Among the injuries which may be associated with the fracture are

dislocation at the shoulder, laceration of the soft parts, and contusion or rupture of bloodvessels or nerves. The latter deserve especial attention because of the gangrene of the limb or the paralysis which may result and may be attributed to negligence in the treatment. The brachial artery or vein or both may be so crushed and bruised by direct violence, as in the passage across the limb of the wheel of a heavily laden wagon or railway car, that a thrombus forms immediately within it and arrests the circulation; or, more rarely, the injury to the vessel may be caused by the sharp edge of a displaced fragment, or the vessel may be stretched across the fragment in such a way as to be occluded by pressure.

A very few cases have been reported in which the injury to the artery has resulted in the formation of an aneurism. Thus, Laurent[1] reports an unpublished case treated by Velpeau: A lad 10 years old broke his humerus in the middle by a fall from an ass. The next day the surgeon noticed at the level of the fracture a tumor as large as a walnut with expansive pulsation and distinct bruit. Velpeau and Richet were called in consultation and immediately tied the artery above and below the tumor without opening the sac. Recovery was complete.

Another case is quoted by the same writer from John and Charles Bell (*Principles of Surgery*, vol. iv. p. 407), but it was observed very incompletely. The patient was a woman 50 years old, and the fracture apparently was caused by direct violence. She survived eight months; the shaft of the bone was almost entirely absorbed, and its periosteal sheath was adherent to the inner surface of the aneurismal sac.

The principal nerve trunks may be injured in like manner; and in addition the musculo-spiral nerve, which is particularly exposed to injury by its close relations to the bone, may be compressed by slipping in between the fragments or by inclusion in the callus.

The *causes* of fracture are external violence and muscular action; a variety of the former which is exceptionally frequent in this region is that exerted during parturition in the manipulations of the accoucheur or by the contractions of the uterus, the latter breaking the bone either as they force it past the fixed parts of the mother or possibly by their own direct action upon it. Fractures by muscular action are much more frequent in the humerus than in any other bone, and the efforts which have produced it have not always been very great. Illustrative examples are given in Chapter IV. Fractures by external violence are direct or indirect, the latter being commonly produced by falls upon the hand. Exceptional causes have been observed, such as that in the case reported by Lonsdale of a man 24 years old who broke his humerus at the junction of the lower and middle thirds by striking a man with his fist, and in several others by the effort to reduce an old dislocation.

Compound fractures have no anatomical peculiarities that require mention here. Gurlt collected five remarkable cases of almost complete severance of the arm by a blow with an axe or sabre, all of which recovered with preservation of the limb. In all the wound was upon the outer and anterior aspect of the limb.

[1] Des Anévrysmes compliquant les Fractures. Thèse de Paris, 1874.

The *symptoms* are the usual ones: abnormal mobility, crepitation, loss of power, pain, and more or less displacement and deformity. Important complications, such as coincident dislocation and injury of the artery or nerve, are accompanied by special symptoms. Those of the former are the local ones of dislocation, lacking only the characteristic changes in the position of the elbow and lower part of the arm, which are here modified by the fracture. Injury to the artery is indicated by absence or weakness of the radial pulse, either immediately after the accident or beginning after the lapse of a few hours. An example of gradual occlusion of the brachial artery by a firm clot followed by gangrene of the limb was quoted from Stromeyer in Chapter VII. In other cases the symptoms have appeared gradually, the pulse becoming weak and finally disappearing, the fingers and hand numb and cold, the surface bluish and livid, and direct examination of the parts after amputation or death has shown a clot occupying a larger or shorter portion of the artery, sometimes firm, pale, and adherent, sometimes dark and soft.

Injury of a nerve is shown by paralysis, loss of sensation, or hyperæsthesia in the parts supplied by it, manifesting itself immediately after the injury, or only after the consolidation of the fracture and the removal of the dressings. Paralysis or loss of sensation indicates division or destruction of the nerve; hyperæsthesia indicates irritation, usually by pressure.

A simple fracture in an adult, running its course without complications, will be solidly reunited in from four to six weeks, and in three or four weeks in children. The possible complications are inflammation and delayed union; the former is sometimes quite marked, ending even in suppuration and partial necrosis, and the latter as has been stated elsewhere, is of much more frequent occurrence in the humerus than in any other bone. The general and local causes that lead to delay in a failure of union have been discussed elsewhere. It is held by many that the special reason in the case of the humerus is to be sought in defective immobilization of the fragments, and Dr. Hamilton has recommended that the limb should be dressed with the elbow extended, in order to secure better fixation. When the elbow is bent at a right angle any vertical movement of the hand or forearm is likely to cause horizontal movement of the lower fragment on the upper one, and lateral splints cannot be fitted accurately or snugly enough to prevent it.

When the fracture is near one or the other end the movements of the corresponding joint may be limited by the mechanical effects of an unreduced displacement, as when the upper fragment slips down in front of the elbow, or entirely abolished by ankylosis resulting from an exuberant callus or the ossification of portions of the capsule.

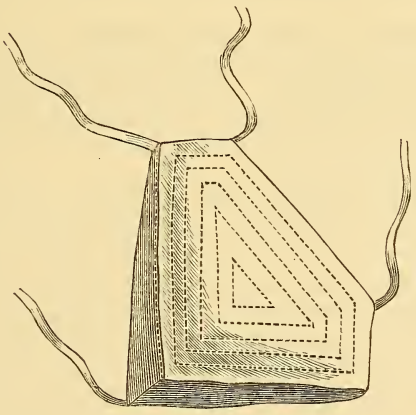
The *prognosis* is relatively favorable; the shortening, according to Hamilton, will average about half an inch in those cases in which any results, and is of no practical importance since it produces no disability and is not noticeable as a deformity.

Treatment.—In making reduction the forearm should be flexed and extension made by drawing upon it or the condyles while counter extension is supplied, if necessary, by an assistant with a band under the axilla, or grasping the shoulder. Gradual extension by weight, or by

an elastic cord, may be necessary in some cases. The treatment in fractures of the upper two-thirds is essentially the same as in fractures of the surgical neck; rest in bed, with permanent extension, and the limb supported upon cushions, may be required at first, and the same combination of external and internal moulded splints will be found useful. The plaster of Paris bandage is in very common use and furnishes good results, but it needs careful watching at first, both to detect displacement and to prevent strangulation of the limb. It should be carried from the hand to the shoulder and may include a few spica turns over the shoulder and about the chest to aid immobilization and oppose the production of overriding by retraction of the muscles. It is convenient to have the forearm flexed and supported by a sling, and if the dressing is properly made and solid, there is, I think, no danger of undue mobility at the seat of fracture. The plaster dressing is, in this respect, much more secure than any made of simple splints, and renders unnecessary the precaution recommended by Dr. Hamilton of dressing the limb with the forearm in the extended position.

I have found it desirable in cases of fracture by direct violence, especially in women and the alcoholic, to keep the patient in bed and the limb supported upon cushions with moderate permanent elastic extension for about a week, or until the danger of acute inflammatory complications had passed, and then to put it up in plaster. Stromeyer's cushion, designed particularly for the treatment of compound fractures of the humerus, is very useful as a support, while extension is made. It is in the form of a pyramid constructed upon a triangular base (fig. 207) the

Fig. 207.

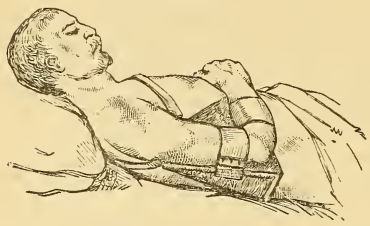


Stromeyer's axillary cushion.

long lines of which are from twelve to fifteen inches in length. It is made of stout muslin or duck, filled with hair or bran, and firm enough to keep its shape under pressure. I have found it advantageous to make the upper end rather more blunt than as shown in the figure. It is secured in place (fig. 208) by tying the upper pair of straps about the opposite

shoulder and the lower pair about the waist. It can be used also temporarily in the place of a splint during the first few days while the patient is not confined to the bed, and while the surgeon is waiting for a swelling to subside; the wrist alone should be supported in a sling, in order that the weight of the elbow may make the necessary extension.

Fig. 208.



Stromeyer's cushion.

If the fracture has been neglected for some time, or if for any other reason shortening has occurred and cannot be reduced by ordinary means, additional extension can be made by suspending a weight from the arm while the patient sits up or moves about. I was able in one case to overcome almost completely by this means shortening to the amount of nearly two inches in the fourth week, using a weight of ten pounds.

It has been thought by some that a cause of failure of union is to be found in longitudinal separation of the fragments by overextension due to the weight of the limb alone. This explanation seems improbable, except in the case of the weak and feeble whose muscles may have lost most of their power, but such a separation might be obtained by force, and preserved either by permanent extension or by splints. Dr. Hamilton mentions a case in which he obtained union with an increase in the length of the limb amounting to half an inch. If the observation was correct, and if the limbs were originally of equal length, the lengthening must have been obtained by overextension, but the possibility of a pre-existing inequality in the length of the limbs weakens the value of the inference.

Care must be taken in applying any dressing or splint to restore and preserve the normal relations of the two fragments, especially with reference to rotatory displacement. The best guide for this purpose is to be found in the outer condyle and the greater tuberosity, since an imaginary line drawn from one to the other when they are in place is parallel to the axis of the bone.

In the treatment of compound fractures of the humerus the general principles laid down in the chapter on treatment are to be followed. In the case of a small wound due to perforation by a fragment an occludent dressing will often convert the fracture promptly into a simple one. Jonathan Hutchinson[1] recommends strongly that the ends of the bone should be resected whenever the opportunity offers. He says "the more you take, within reasonable limits, the easier will be the subsequent treatment and the better the ultimate result. But you must leave the periosteum." This advice certainly needs qualification. It is based upon the idea that the tendency to shortening cannot be readily overcome, and that the projection of the fragments will interfere with union. In a transverse fracture there is no tendency to shortening after reduction has been made, and in an oblique fracture the resection, if limited

[1] Medical Times and Gazette, 1866, i. p. 360.

to one fragment, would not prevent shortening, and would, on the other hand, interfere materially with union, because one of the surfaces would be oblique and the other transverse, in part at least, and their area of contact would be small. A better rule is to resect only when resection is necessary to reduction, or when some especial reason for it, other than the fear of displacement, exists. Stromeyer's pad will be found very useful during the period when fixed dressings cannot be conveniently worn.

When there is reason to fear serious injury to bloodvessels or nerves fixed dressings and bandages should be avoided until after the limits of the injury have become apparent, in order that no question may arise as to the cause of the gangrene or sloughing, if either occurs. Reduction should be made as completely as possible, and the limb supported upon pads or cushions.

3. Fractures of the Lower End of the Humerus.

This group, like that of fractures at the upper end of the humerus, includes a number of varieties differing materially in character and importance, and having in common only their position near the elbow, and the frequent necessity and difficulty of making a differential diagnosis between each and the others and dislocation. A certain lack of agreement among writers, as to the sense in which some of the distinguishing terms are used, makes it desirable to define those that are to be here employed at the same time that the limits of the divisions of the main group are traced. These divisions are:—

1. *Fractures above the Condyles.*—The line of fracture crosses the expanded part of the bone above the articular surface transversely or obliquely, and may or may not open the articulation.

2. *Fractures of the Internal Epicondyle or Epitrochlea.*—The line of fracture is entirely extra-articular, and the piece broken off consists of the whole or part of the epicondyle. And by the internal epicondyle or epitrochlea, is meant the whole of the projecting tuberosity that lies above and on the inner side of the trochlea, and part of which is developed about a separate centre of ossification.

3. *Fractures of the External Epicondyle.*—The line of fracture is probably extra-articular; the fragment is very small, consisting of the epicondyle proper, either alone or with some of the adjoining bone.

4. *Fractures of the Internal Condyle.*—In these the line of fracture passes from a point on the inner border of the bone above the tip of the epicondyle obliquely downward and outward to the articular surface.

5. *Fractures of the External Condyle.*—Similar to the preceding variety, except that the line of fracture begins upon the outer side and passes downward and inward.

6. *Intercondyloid Fractures.*—These are a combination of the 1st, 4th, and 5th, the extremity being separated from the shaft and split into two or more pieces.

7. *Separation of the Epiphysis.*—The fracture follows the line of the conjugal cartilage.

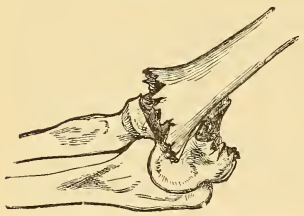
8. *Fracture of the Articular Process.*—In this more or less of the

portion of bone covered by articular cartilage is broken off, the general direction of the line of fracture being transverse.

9. *Simultaneous Fracture of the ends of the Humerus, Radius, and Ulna forming the Elbow-joint.*

1. Fractures above the Condyles.—These fractures are those which come next in order of position after fractures of the lower third of the shaft and require separate mention because of the special questions involved in the differential diagnosis by reason of the proximity of the elbow-joint, and by the possible extension of the fracture into the joint. The line of fracture may be transverse or oblique, and oblique either from side to side or from before backward, and it may open the joint by crossing the olecranon or coronoid fossa or by the extension into it of a fissure. When the line that extends into the joint is more than a fissure it may not be easy to determine whether the case belongs to the first or to the sixth class, and the division is therefore to a certain degree arbitrary. In some cases too there is, in addition to the transverse fracture, a separate fracture of either condyle, particularly of the inner one. The displacement is usually very notable, the most common one being overriding of the upper in front of the lower fragment combined with more or less angular displacement (fig. 209), this overriding interferes with the action of the joint by interposing an obstacle to flexion and by exuberant ossification and the production of fibrous bands. Figure 210 represents a fracture partly transverse and partly oblique without displacement, and figure 211 represents another in which the lower fragment is displaced forward and inward, and so turned as to occupy a position at right angles to its natural one with its articular surface directed forward; its surface of fracture is in contact and united with the anterior surface of the upper fragment.

Fig. 209.



Supra-condyloid fracture of the humerus. (Hutchinson.)

In compound fractures by indirect violence the usual displacement is of the lower end of the upper fragment through the tissues on the anterior aspect of the limb, sometimes raising and stretching the artery and median nerve.

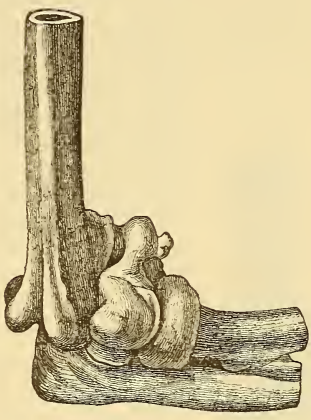
The *symptoms* present a considerable diversity corresponding to the variations in the line and extent of the fracture and the direction of the displacement, but as a rule the limb appears to be shortened, and the olecranon is often exceptionally prominent behind, so that the impression given by its first inspection is that the injury is a dislocation. Its true character appears on examination if the surgeon can recognize that the relations of the tip of the olecranon with the epicondyles are unchanged and that the normal motions of the joint are preserved. Crepitation may usually be obtained, but forcible extension is sometimes needed to bring the fractured surfaces into contact again. In all injuries about the elbow one of the first points to be determined is the relative position of the two epicondyles and the end of the olecranon, and this is most conveniently

done by placing the thumb and middle finger upon the epicondyles and the index finger upon the olecranon and noting their correspondence with those of the other side in the positions of flexion and extension.

Fig. 210.

Supra-condyloid fracture of the humerus.

Fig. 211.



Supra-condyloid fracture of the humerus; union with displacement.

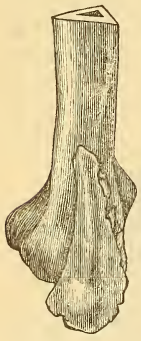
The treatment in simple fractures is to place the arm in a rectangular grooved posterior splint reaching from the shoulder to the wrist, supplemented if necessary by a short anterior one upon the arm to aid in preventing projection forward of the upper fragment. Or, if the tendency to displacement is slight the limb may be placed in a plaster dressing.

In compound fractures it is strongly urged by some writers that the bone should be freely excised in order that the subsequent treatment may be made easier. There can be no question as to the propriety of this interference when it is necessary to reduction, or when the tendency to displacement is great and not to be easily overcome, but I do not think it should be laid down as a formal rule of treatment to be followed in every case before the tendency to displacement has manifested itself to its full extent. The limb should be inspected frequently during the first week or fortnight with a view to correct any recurrent displacement, and in consideration of the exceptional importance which the proximity of the joint gives to displacement. I am disposed to give the preference to splints rather than to complete encasement in plaster. Under the latter displacement may occur and remain undetected until it is too late to apply a remedy, while the former may be so fashioned as to leave the joint open to frequent inspection without pain or inconvenience and thus enable the surgeon to obtain timely warning of the necessity for interference.

2. Fractures of the Epitrochlea or Internal Epicondyle.—By the epitrochlea is meant all that projecting portion of bone which lies on the inner side and above the level of the trochlea; its lower limit is the horizontal border of the bone where it projects at right angles to the

side of the trochlea and is therefore perfectly well defined, but above it is continuous with the condyloid ridge and its limit must be fixed arbitrarily. In its development it proceeds partly from the shaft or internal condyle and partly from a separate centre of ossification at its apex, to which part the term *internal epicondyle* is sometimes restricted. In the classification which I have adopted this group includes all extra-articular fractures involving more or less of this projecting part of the bone on the inner side, and no distinction is made between those which involve the small epiphyseal portion alone or the line of its junction with the remainder, and those in which a larger piece is broken off or in which the line of fracture crosses the epiphyseal line. This latter distinction has led to some discussion, but its interest is purely statistical; practically there is no difference in the treatment or in the results, and furthermore the diagnosis (differential as between the two) cannot be made upon the living with anything like certainty. No fracture limited to the epiphysis alone or following the epiphyseal junction has been verified by direct examination while recent, except as part of an extensive fracture, but there are many cases of fracture, especially in children, in which the clinical evidence has pointed strongly to diastasis or fractures of the epiphysis proper. Gurlt knows of only one specimen of united fracture; it is preserved in the collection at Wurzburg and is represented in fig. 212. The fragment includes the epitrochlea and a portion of the shaft above it, and is displaced downward nearly an inch.

Fig. 212.



Fracture of the internal epicondyle of the humerus (epitrochlea). (Gurlt.)

Dr. Hamilton presented to the New York Surgical Society in 1880, and describes in the sixth edition of his valuable work on Fractures, some specimens sent to him by Dr. Zuckercandl, of Vienna, of supposed diastasis, or fracture outside of the epiphyseal line of both the internal and external epicondyles. The specimens were found in the dissecting room, and were without history. The one which was thought by Dr. Zuckercandl to show an old fracture of the internal epicondyle presented, as Dr. Hamilton points out, besides the supposed epicondyle displaced downward, the signs of a former more extensive fracture, and it must therefore remain doubtful, not only whether the small displaced fragment was actually the epiphyseal epicondyle, but also whether its separation was not merely an incident in, a part of, a much more extended and important lesion. Dr. Lange reported at the same meeting of the Society a case of compound fracture of the elbow in a lad, in which the main epiphysis was broken off, and also each epiphyseal epicondyle, the fracture following the line of the conjugal cartilage in each case. While such cases go to prove what can hardly be thought to need proof, that the epicondyle can be separated, they certainly do not deserve to be classed as fractures of that limited part.

There are a few other cases which show that fracture of the epitrochlea, communicating however with the joint, may accompany dislocation of the bones of the forearm backward and outward, resembling in

some respects the fracture of the greater tuberosity which may accompany dislocation of the shoulder. In one case[1] ankylosis followed, excision was done seven months afterwards, and the direct examination thus afforded showed the fragment lying in the olecranon fossa. Similar clinical cases are quoted by Gurlt.[2] The patients were 10, 16, 28, and 38 years old.

The first author who called attention to this variety of fracture was Granger,[3] in 1818. It is more common in children than in adults, although it is generally held that this apophysis is longer in the latter than in the former, and, therefore, theoretically more liable to fracture. Granger claimed that the fracture was the result of muscular action, of an effort made in a fall upon the hand, but Malgaigne interprets the facts very differently and invokes a direct cause, external violence exerted directly upon the apophysis. In some cases the evidence of the violence appears to have been complete, and the theory of the intervention of this cause seems to me to receive additional support from the greater frequency of the lesion in the young, those whose muscles are comparatively weak, and whose efforts to save themselves from injury are comparatively feeble. Any one who has observed a child fall must have noticed how thoroughly he does it, how slight and tardy the apparent effort to save himself. In one of the two cases of this injury which have come under my own observation everything favored the theory of a fracture by direct violence. The patient was a girl 13 years old who, while skating upon rollers, fell back upon the sidewalk, striking upon the inner side of her right elbow. She said she had felt something out of place after she fell and had slipped back a little lump by pressing it, indicating the epitrochlea as the lump. She was seen immediately after the accident by Dr. Keyes, who was able to grasp the epitrochlea between his thumb and finger and move it. At his invitation, I saw the case the following day, and found the region very tender and swollen, and occupied by a large ecchymosis. There was no interference with the motions of the joint.

In the other case the mechanism was more complex. A boy, 11 years old, fell from a fence, striking upon the right side with his right arm bent under him. He was brought immediately to the Presbyterian Hospital; there was no bruise, the arm was extended and could not be flexed, and the deformity was described by the house surgeon as a prominence behind on the outer side, and a depression in front in the flexure of the joint. It was thought to be dislocation, and was reduced without noise or jar by drawing the forearm gently forward. I saw the patient on the following day, found the joint normal in form and function, except that extension was incomplete and painful; rotation of the forearm perfectly free and painless; and a small hard lump, movable with distinct crepitation, could be felt at the site of the epitrochlea; its range of motion was about one-fourth of an inch when the arm was semi-flexed, less when it was extended. The arm was kept in a rectan-

[1] Langenbeck's Archiv, vol. iii. 1862. p. 31. No. 139.
[2] Loc. cit., vol. ii. p. 823, Cases 305, 306, 307, 308.
[3] Edinburgh Med. and Surg. Journal, vol. xiv. p. 196.

gular splint, and the patient made a good recovery with complete range of motion, but the fragment united with displacement downward to the distance of a quarter of an inch.

I am not sure of the character of the associated injury in this case; possibly it was a partial separation of the epiphysis or of its trochlear portion, an accident which would render the diastasis of the epitrochlea easier.

The *symptoms* vary somewhat with the size of the fragment, for when the latter is small it is held in place by the untorn portion of the muscular attachments which are inserted upon the adjoining portions of bone; but when it is large enough to include the greater part of the attachment displacement takes place downward and forward in the direction of the muscles. If the swelling is not too great the fragment can be recognized, seized between the thumb and finger, and moved, usually with crepitation. As above remarked, the extent of this mobility in one of my cases was affected by the position of the forearm. Ecchymosis is common, and the functions of the joint are diminished either by pain or by fear of exciting it. In one of Malgaigne's patients, a man 51 years old, the attached muscles appear to have remained for some time in a state of spasm or watchful contraction which greatly limited the movements of the forearm.

In a few cases the ulnar nerve has been injured by the original violence or irritated by pressure of the displaced fragment or a portion of callus. In three of Granger's cases there was partial paralysis of motion and sensation in the region supplied by the ulnar nerve, and repeated crops of vesicles formed upon the corresponding part of the hand during the two or three months following the injury. All the symptoms disappeared after a time. Richet[1] observed a case of fracture of the epitrochlea with dislocation of the elbow inward due to a fall upon the ice. After reduction of the dislocation the ulnar nerve was found to be completely paralyzed. A month later the little finger was so insensitive that the patient amused himself and amazed his playfellows by holding it for more than a minute in the flame of a candle. The deep burn which was the result took several weeks to heal, and afterwards sensibility returned gradually and became complete.

Denucé[2] was consulted by a man suffering with an intense neuralgia of the ulnar nerve following a fall upon the elbow three months before. He recognized deformity of the epitrochlea, made an incision, and found the nerve hypertrophied and resting upon a bony prominence formed by the epitrochlea displaced and united in its false position. The projecting part of the bone was excised, and the neuralgia ceased.

The reaction is seldom severe, and when so, it appears to be mainly the result of the contusion which has caused the fracture, or possibly of an associated sprain. Nevertheless there is frequently mentioned in the recorded cases a degree of temporary limitation of the movements of the joint, which seems quite disproportionate to the injury; thus, in one of

[1] Anatomie Medico-Chirurgicale, 4th ed., p. 672, note.
[2] Dict. de Méd. et Chir. Pratiques, art. Coude, p. 721.

Malgaigne's cases the range of motion two and a half months after the accident was only 60°, or about only half as great as it should be.

The *treatment* is simple: immobilization of the elbow in the flexed position so as to relax the muscles that arise from the epitrochlea and thus diminish the force that tends to draw it forward and downward. It is of doubtful utility to attempt to keep the fragment in place by pressure upon it from the outside. Even if it remains displaced downward and forward the deformity is slight and entails no loss of function. Immobilization should be maintained until consolidation has taken place, the length of time necessary for which varies with the age of the patient and the extent of the unreduced displacement. In children, and without displacement, union is sufficiently firm at the end of ten days or a fortnight to allow splints to be laid aside and the arm to be carried in a sling, and in three weeks the arm may be left unsupported and free. Most authors recommend that passive motion should be begun during the second or at the beginning of the third week; but if the joint is not inflamed passive motion is useless, and if it is inflamed absolute quiet is what it most needs. The slight movements permitted by a sling in cases in which the joint is not painful are sufficient to keep it from stiffening, and the limitations of motion which follow prolonged immobility do not long withstand regular exercise after the injury has been repaired.

Quite recently Pauly[1] has removed the fragment through an incision on the theory that this would diminish the chance of an excessive formation of callus. As this chance does not appear to be at all great, I think most surgeons will postpone operative interference until the actual need arises.

3. Fractures of the External Epicondyle.—This is a much rarer accident than the preceding, and as the fragment that is broken off is small, and as the cause appears to be always direct violence, which is usually accompanied by bruising and swelling, the exact nature of the injury may easily pass unrecognized. An anatomical demonstration of the fracture has never been made, except in connection with more extensive fractures of the elbow. Zuckercandl's supposed specimen, to which reference was made in the preceding section, appears to have been only an irregular deposit of bone in the external lateral ligament. In the discussion which followed the presentation of these specimens to the New York Surgical Society, Dr. McBurney said he had found in the dissecting room similar isolated pieces of bone resembling detached epicondyles and existing symmetrically at both elbows, a fact which makes the intervention of a traumatic cause extremely improbable.

In the sense in which the term is here used the epicondyle is the small prominence above and on the outer side of the capitellum, composed in part of bone formed about a separate centre of ossification, and in part of the projecting portion of the shaft or condyle itself. To it are attached the external lateral ligament of the joint and some of the extensor muscles of the forearm.

Most surgeons deny the possibility of an extra-articular fracture of

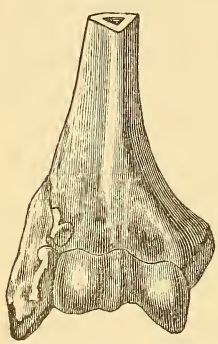
[1] Centralblatt für Chirurgie, 1882, p. 157.

this part, and group all fractures of the region as of the external condyle. Anatomically speaking it is certainly possible for such a fracture to occur; the epicondyle, though small, is still large enough to be broken in such a way that the line of fracture may lie entirely outside the joint. Coulon[1] quotes the following case that was under his observation during his internat at the Hôpital Ste. Eugénie (Children's Hospital), and adds that Marjolin, the attending surgeon, saw similar ones every year. The observation is entirely clinical, and may therefore be considered not entirely demonstrative.

Paul G., 3½ years old, fell to the sidewalk from a chair on the 15th of October, 1860, and was brought to the hospital some time after the accident. The right elbow was swollen and there was an ecchymosis on the outer side; pressure at the ecchymosis disclosed abnormal mobility and crepitation, leaving no doubt of the existence of a fracture of the epicondyle; the epicondyloid fragment could be grasped between two fingers and felt to be very small. As there was no displacement Marjolin applied no splints, but simply kept the child in bed with the arm upon a cushion and covered with compresses wet with tincture of arnica. Consolidation was complete by the 25th; the child was allowed to go about with the arm in a sling, and passive motion of the joint was made. On the 15th of November the child left the hospital, the movements of the joint were complete, the epicondyle was a little larger, more rounded, and less prominent than the one on the other arm. *The smallness of the fragment, and the absence of articular rigidity after consolidation led us to make the diagnosis of an extra-articular fracture.* Italics in the original.

Gurlt[2] describes as extra-articular fractures of the external epicondyle two specimens preserved, the one at Giessen, the other at Berlin. In each the fracture has united with considerable displacement downward of the fragment which appears in the description and figure (fig. 213) too large to have been entirely extra-articular. Still, his personal examination of the specimens was more likely to lead to a correct opinion of them than a verbal description or a figure is.

Fig. 213.



Fracture of the external epicondyle of the humerus. (Gurlt.)

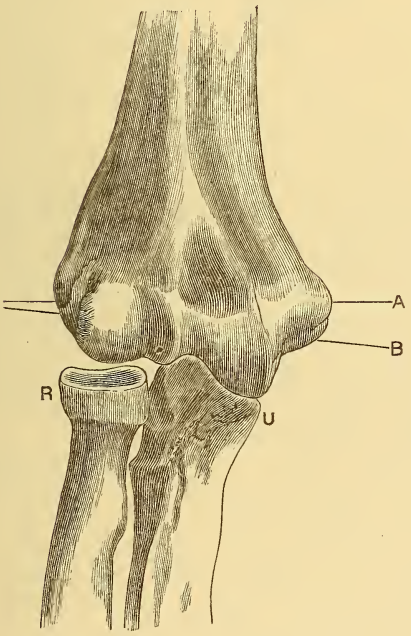
There is little to be added. The cause must be direct violence; the displacement must be slight and unimportant; the treatment, rest and soothing lotions.

4. Fractures of the Internal Condyle.—This is one of the commoner, the more frequent varieties of fracture at the elbow, and one of the most important, because, beside being intra-articular and thus exposing to the usual disabilities incidental to such fractures, it includes the part of the articulation which is in relation with the ulna, and therefore any alteration in the relations of the parts which imposes a mechanical obstacle to motion interferes at once with the principal

[1] Des Fractures chez les Enfants. Paris, 1861, p. 143.
[2] Loc. cit., p. 798.

function of the joint. Physiologically speaking, the elbow-joint consists only of the humero-ulnar articulation. The association of the radius with it serves to increase the breadth and thereby the strength and solidity of the hinge, but this association is not essential to the proper performance of the functions, either of it or of the radius. The head of the radius merely rests against the humerus, while the ulna embraces its corresponding articular surface over an arc of nearly half a circle, and has in addition a central ridge running in the direction of its motion which fits into a corresponding groove upon the trochlea and opposes lateral displacement. The axis of the joint is inclined to the long axis of the humerus, so that when the latter hangs directly down the forearm

Fig. 214.



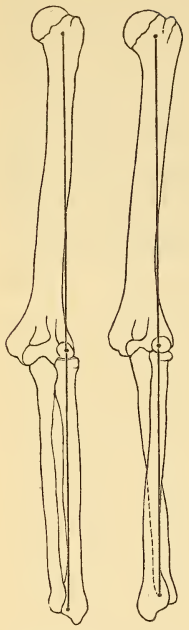
Showing the relations of B, the axis of the elbow-joint, to A, a line drawn perpendicular to the long axis of the humerus. (Tillaux.)

Fig. 215.

The outward deflection of the fore-arm. The "carrying function."

is directed somewhat outwardly, away from the body, at an angle that varies in different individuals and even in the arms of the same individual. This angle favors that use of the arm to which Dr. Fowler, of Brooklyn, gave the name of the "carrying function," since it removes the hand to a convenient distance from the thigh when the arm hangs

Fig. 216.



Showing the transmission through the external condyle of a force received upon the palm.

down with the elbow resting against the hip and the hand supinated. In addition this angle causes the direct line of transmission of a force received upon the ball of the hand when the elbow is fully extended to pass through the head of the radius and the external condyle, as shown in figure 216, and not through the ulna and internal condyle. It appears probable to me that, in consequence of this arrangement, many fractures of the external condyle are due to direct transmission of force in a fall upon the hand, and that fractures of the internal condyle, other than those caused by a blow upon the elbow, may be produced in either of two ways: 1st, transmission of force through the ulna, acting either directly in the line of its long axis, or transversely so as to turn the forearm laterally towards the inner side upon the head of the radius as a centre; or, 2d, by a force acting in the opposite direction to that last named, turning the forearm towards the outer side and tearing off the internal condyle by means of the internal lateral ligament. In the 1st, the fragment would be displaced upward and backward; in the 2d, downward. I am disposed to consider the 2d one as the mechanism of those cases of fracture of the epitrochlea with partial dislocation of the forearm mentioned above.

The loss of this divergent angle in consequence either of the ascent of the internal condyle or of the descent of the external condyle is the essential part of the deformity seen so frequently after "fracture of the elbow" and represented in fig. 217 which I take from a valuable and interesting paper by Dr. Oscar H. Allis[1] upon this subject.

The line of fracture runs from a point above the epitrochlea obliquely downward and outward to the articular surface, crossing the olecranon fossa, and terminating at a variable distance from the inner edge of the trochlea, but usually, according to Hamilton, at the centre of the latter.

The usual displacement is of the lower fragment upward and backward, and is due either to the action of the original force, or to the contraction of the biceps, triceps, and brachialis anticus, or, as Dr. Allis has pointed out, to the pressure of the bandages and splints. The ulna remains attached to the fragment by the internal lateral ligament and follows it in its displacement, or it prevents displacement in some cases by preserving its own relations to the other parts of the joint, a condition which is undoubtedly favored greatly whenever the line of fracture passes near the inner edge of the trochlea and the fragment is a small one. In exceptional cases the displacement is forward or downward.

Dr. Markoe[2] was the first to call especial attention to the fact that

[1] Annals of the Anatomical and Surgical Soc. Brooklyn, Aug. 1880.

[2] N. Y. Journal of Med., 1855, p. 382; and N. Y. Medical Record, 1880, vol. xviii. p. 118.

with this injury there may be associated dislocation of the radius backward, that is, displacement backward of the radius, ulna, and fragment, these three pieces preserving their relations to each other, a complication that is most disastrous in its results if not promptly recognized and

Fig. 217.

Deformity after fracture at the lower end of the humerus. (Allis.)

corrected. An instance of this kind was reported before Dr. Markoe wrote upon the subject, but it appears to have attracted no attention; Gurlt (loc. cit., vol. ii. p. 820) quotes the case from Michaux.

The symptoms are independent mobility of the condyle, crepitation, and displacement. The first two are obtained by grasping the condyles with the fingers of either hand and moving them backward and forward upon each other, or by grasping the lower portion of the arm with one hand and moving the forearm with the other. Displacement of the condyle is recognized by ascertaining its relations to the other condyle and the olecranon and comparing them with the known standard or with those of the other arm. When the forearm is fully extended a line joining the two epicondyles crosses the tip of the olecranon, if the parts are in their normal relations, and as the forearm is flexed the olecranon sinks below this line. If there is displacement backward there is marked resemblance to a dislocation in the projection of the olecranon when the forearm is flexed and in the disappearance of this projection when it is extended. Sometimes the transverse diameter of the lower end of the humerus is appreciably increased, but even under the most favorable circumstances this is not easily recognized and the swelling may be sufficient to mask it completely.

In fracture with dislocation backward of both bones the leading features, according to Dr. Markoe are: 1st, the resemblance to a dislocation backward; 2d, the preservation of the relations of the internal condyle and the olecranon, the position of the head of the radius below and behind the external condyle, and the abrupt ending of the condyloid ridge of the humerus in a sharp projection about an inch above the joint; 3d, the independent mobility of the fragment with crepitation; and 4th, the termination of the humerus in front in a sharp small prominence.

The displacement is easily reduced and reproduced. The following case taken from Dr. Markoe's last paper on the subject is fairly typical:—

"Michael Lee, aged 10, was admitted to the New York Hospital October 11, 1859. Five days before he had fallen from a horse, striking on his left side, with his arm twisted under him. Great swelling and ecchymosis took place immediately. On the 17th the swelling had so far subsided as to give us a chance to examine the fracture. The internal condyle and olecranon were in proper relation to one another, while the head of the radius had left the external condyle, and was easily felt rotating behind and to the outside of it. The whole aspect of the elbow was that of dislocation backward, and the end of the humerus making a rounded projection on the anterior face of the joint. The parts were so easily movable that it could further be distinctly made out that a considerable fragment of the internal condyle, broken from the shaft of the bone, remained attached to the olecranon and moved with it. The whole displacement could be easily reduced and the deformity removed, while on letting go the limb it was immediately reproduced. Dr. Van Buren saw the case with me and recognized the facts as above stated, and without hesitation agreed with me in the diagnosis of fracture of the internal condyle, involving so much of the basis of support of the olecranon as to allow of its displacement backward to a sufficient extent to permit the head of the radius to be also pushed backward, as in ordinary luxation. The displacement was reduced, and the arm placed at an angle less than a right angle and so retained by an angular tin splint, a firm pad being placed on the prominent end of the humerus to keep it in place. On the 30th the apparatus was removed without my knowledge, and the young man reported that union of the detached fragment was firm and the joint in good shape. He was discharged December 1st without my having had an opportunity of examining the arm."

The following case reported by Coulon[1] may serve as an example of the cases not complicated by dislocation, a simple fracture extending through the trochlea.

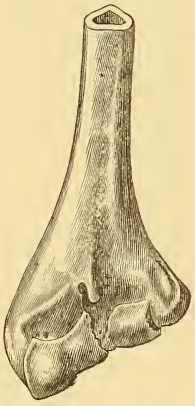
A child, four years old, was brought to the hospital two hours after she had fallen down a staircase. The elbow was swollen, the forearm slightly flexed upon the arm, the relations between the olecranon and epicondyles normal. Pressure upon the epitrochlea produced crepitation, but the swelling made it impossible to recognize the size of the fragment or the extent of the mobility. Flexion and extension were rendered almost impossible by the swelling and pain. The limb was partly flexed and fastened upon a hard cushion and treated with poultices and arnica, and on the fifth day placed in a gutta-percha splint. On the seventeenth day there was no longer crepitation or mobility; after the twenty-first day the arm was left in a sling and forcible passive motion was made every day. At the end of a month she left the hospital; the arm could be flexed to a right angle and extended to an angle of 140°, the epitrochlea was displaced inward and forward, and the fragment could be felt to be voluminous. Two and a half months

[1] Fractures chez les Enfants, Paris, 1861, p. 159.

later the condition was the same, although the parents claimed to have made forced passive motion.

The course of the case is usually simple and uncomplicated, the swelling and ecchymosis disappear after a few days, the fragment reunites with the shaft, and the process of repair is practically terminated in the course of four or five weeks. But the tendency to displacement, to reunion of the fragments in a position that interferes more or less seriously with the functions of the joint, is great, and not easily overcome; and in young people there is an equally dangerous tendency, one which exists in all fractures near to or involving joints, to overgrowth of callus to an extent and in positions which may greatly restrict the movements of the joint. Among the displacements the one above mentioned, fig. 218, which consists in the elevation of the inner condyle and the consequent loss of the outward deflection of the extended forearm from the line of the arm, is to be especially borne in mind.

Fig. 218.



Fracture of the internal condyle of the humerus; displacement upwards; union. (Gurlt.)

Dr. Weir Mitchell[1] mentions a case of inflammation of the ulnar nerve following seven years after a fracture thought to be of the internal condyle and caused by direct violence. The pain was so severe that the patient sought amputation. Dr. D. H. Agnew excised two and a half inches of the nerve just above the elbow with immediate and permanent relief of the pain. Three months after the operation motion and sensation had been completely restored in the region supplied by the nerve.

The *treatment* consists in reduction of the displacement and of the accompanying dislocation, if there be one, and retention by dressings designed to act upon the fragment, not directly, but through the ulna which remains attached to it. The usual, almost universal, treatment has been to fix the arm upon a rectangular internal lateral or posterior splint, and to begin passive motion not later than the third week. The results of this are certainly not satisfactory; union with displacement, as above described, is common, and more or less rigidity of the joint not infrequent, and there are those who now claim, with much apparent reason, that these defects are, to a certain extent, the consequences of the inadequate or ill-regulated support of the splint. Dr. Allis called attention to the subject in an impressive manner, and alleged that with a lateral or a posterior splint bound to the arm with a roller bandage the ulna and the attached condyle were not merely not held in place, but were actually pressed upward out of place, and thus the very defect was produced which the surgeon sought to avoid. He claimed that the radius and external condyle formed the fixed point towards which the ulna and internal condyle were drawn by the turns of the bandage. Dr. Allis's explanation does not seem to be entirely satisfactory, because the ascent of the internal condyle is not in the direction in which the pressure of

[1] Injuries of Nerves, 1872, p. 295.

an enveloping bandage would tend to force it; the radius and ulna are in contact at their upper ends, and cannot there be drawn closer together, but if the arm is supported in a sling the support is transmitted through the ulna, which is the undermost part of the forearm, and necessarily presses it upward, so that the inclination of the axis of the elbow-joint is changed in the manner and with the result above described. It is immaterial, so far as this result is concerned, whether the splint is a posterior or a lateral one, for in the former case the ulna rests directly upon it, and in the latter it rests upon the turns of the bandage which binds them together.

The conclusion which Dr. Allis reaches is that the fracture should be treated with the arm in the extended position, and preferably in a moulded splint or immovable dressing. He employs and recommends a simple dressing of strips of adhesive plaster, either used alone or combined with a light, immovable dressing. In the first case he places the limb in an easy, natural, extended position, and covers it with strips of adhesive plaster applied longitudinally, each about an inch wide, and long enough to reach nearly from the shoulder to the wrist. Over this layer he applies a second similar one, and leaves both on for five or six weeks, seeing the case at first every day and then once a week. In the second method he applies three strips, one on each side and one behind, then a layer of cotton batting over the joint and for some distance above and below it, and then a roller bandage. As soon as the cotton is entirely covered by the bandage he smears the surface with a paste made of the white of two or three eggs thickened with flour, applies a second layer of bandage, smears that also with the paste, and finishes with a third layer of the bandage. He adds: "the perfection of the cure will depend wholly upon the natural position assumed by the limb while the dressing is applied. Hence, lay the patient on the back, and with both arms stripped take the sound arm as the guide. When the limb is placed supine, the thumb looking outward, *note that the normal* [*uninjured*] *limb is not straight*, but that an obtuse angle is to be observed on the radial side of the elbow-joint. Observe this in the dressing, and if this is carefully preserved until the paste has hardened there is nothing to fear from displacements."

Dr. Allis declares that this practice has yielded in his hands excellent results; that is, when the dressings were removed the limbs were found free from deformity, and even, in the milder cases, from stiffness. The theoretical grounds upon which the method rests, I believe to be entirely sound, and the practice to be free from objection whenever the extended position does not favor, as it sometimes does, dislocation of the forearm backward. In the extended position, with the head of the radius resting firmly against the capitellum, the internal condyle can be brought fully down by fixing the arm and drawing the wrist gently outward, and so long as the forearm is kept in this position the condyle cannot rise. On the other hand, displacement forward or backward remains easy, and I should be unwilling to trust to the protection supplied by two thicknesses of adhesive plaster, particularly since the extended arm is a much more awkward limb, and one that is much more exposed to accidental violence than a flexed one.

I have not had sufficient experience with the method of treatment in the extended position to say more than that I am myself willing to make use of it, but that I prefer to use a moulded posterior gypsum splint, and a position 30° or 40° short of complete extension, in order to detect any tipping forward of the fragment if it should occur. This preserves the lateral angle, and is a better protection against chance violence ; at the same time the splint can be easily removed and replaced if the surgeon desires to make passive motion.

I do not think early passive motion is necessary to prevent stiffness of the joint; and when it is painful, the pain lasting for some time, I believe it to be actually harmful by increasing and prolonging the inflammation. No harm can come from gently moving the arm once or twice daily through the range of motion which is easy and painless, and, on the other hand, no good can come, in my judgment, from forced motion or from any motion that excites tenderness during the first four or five weeks. The records of cases are filled with instances in which the joint has become almost or entirely rigid under treatment by passive motion, and then after the tenderness had ceased mobility has returned gradually under ordinary daily use of the limb. When there is displacement that restricts motion mechanically, the range may sometimes be increased by forcing gently every day with the hands, or constantly by elastic traction, after consolidation has begun and before it is firm, for the displaced fragment can thus be pressed out of the way ; but the stiffness which is due to peri-articular thickening or intra-articular bands is best prevented or diminished by rest during the inflammatory period, and will afterwards yield to constant regular use, or the bands may be afterwards forcibly broken under ether.

If the extended position proves very inconvenient to the patient, I think flexion at or near a right angle could be safely substituted for it after the first fortnight, with the protection of a moulded splint or immovable dressing, because by that time the tendency to displacement, under the influence of the contraction of the muscles or the weight of the limb, would have been removed by the partial union of the fragments. Indeed, the principal advantage of the extended position appears to be in the certainty of the reduction rather than in the retention. An immovable dressing can be applied to the flexed arm in such a way that it will keep the parts in position and will not press unduly upon the ulna, but the surgeon cannot be certain that the reduction is complete. A change of one-fourth of an inch in the position of the condyle will in most cases be sufficient to destroy the outward inclination of the forearm entirely.

In the cases complicated by dislocation of the forearm backward it has been found necessary to keep the elbow flexed to a right angle, or even a little further, in order to prevent the recurrence of the dislocation. Dr. Markoe recommends for these cases a grooved posterior splint with a short anterior one on the arm, and he begins passive motion in the third week.

5. Fractures of the External Condyle.—These also are among the more frequent fractures at the elbow, and, like those of the internal condyle, are much more common in children than in adults. Of 29 cases

recorded by Hamilton all but 2 occurred in children under sixteen years of age. The fracture may be produced by a fall upon the hand, or by a fall upon the posterior and inner portion of the elbow; in the former case the force is transmitted through the radius; in the latter, in some cases at least, the force is received upon the olecranon or ulna, which is thereby driven forcibly upward and outward, splitting off the external condyle. Ordinarily the periosteum is not torn extensively, and the displacement is not great. The line of fracture runs obliquely from the outer ridge of the humerus downward and inward into the joint, sometimes extending as far inward as the middle of the trochlea. Malgaigne gives in his Atlas, Plates VIII. and IX., illustrations of two fractures of the external condyle, both old and ununited.

Displacement may take place in any direction except inwardly, and is not infrequently accompanied by partial dislocation of both bones of the forearm outward, sometimes by that of the radius alone. Two cases of extreme displacement outward and upward, so that the olecranon lay upon the outer side of the humerus, were reported recently by Franz Schmitz[1] with drawings after dissection. The outer condyle in one was ununited; flexion and extension limited to the arc between 105° and 140°, pronation and supination perfect. A neuritis of the ulnar nerve had been excited by the overstretching of the nerve, and had led to paralysis of the corresponding muscles. The second case was found in the dissecting-room, with no history, and no appearance of nerve trouble.

The radius usually preserves its relations to the condyle, but in a case reported by Dr. Hamilton it was displaced backward and separated entirely from the condyle. The displacement could be easily reduced, but the reduction could not be maintained, and apparently the displacement did not interfere with the functions of the joint.

The symptoms of the fracture vary principally with the degree of the displacement. There are the usual symptoms, swelling, pain, ecchymosis, and crepitation; the latter is obtained most readily by rotating the forearm and by pressure upon the condyle. The anatomical guides in the diagnosis are the same as above detailed in the other fracture: the relations of the olecranon and epicondyles, and the position of the head of the radius. The latter lies normally a short distance below the external epicondyle. If the finger is carried directly downward from the tip of the epicondyle and the forearm is gently rotated the edge of the head of the radius can be felt very distinctly to move to and fro, and whenever the swelling is not so great as to mask the parts this examination will enable the surgeon to determine positively whether the head of the radius is, or is not in its proper place. As the line of fracture is oblique displacement of the fragment upward will always be also somewhat outward, and thus the transverse diameter of the lower end of the humerus will be increased.

The effect of the displacement upon the normal outward deflection of the forearm is to increase it if the displacement is upward, and to diminish it if it is downward. The recorded cases indicate that the former is the

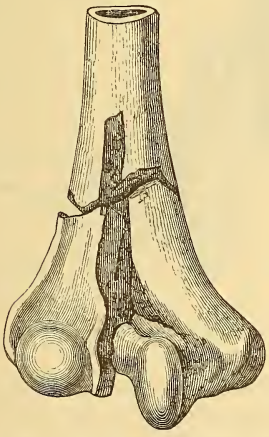
[1] Ein Beitrag zur Chirurgischen Pathologie des Ellbogengelenks, Munich, E. Stahl, 1880, p. 27.

more common; they show also a rather large proportion of cases of fibrous union. The ultimate result, so far as the restoration of function is concerned, varies greatly in the different cases, but is usually good and improves with time.

The treatment consists in immobilization, and usually in the flexed position, because of a tendency to the displacement of the fragment forward and downward by the traction of the attached muscles. A common dressing consists of a grooved posterior rectangular splint extending from the shoulder to the wrist, and a short anterior one extending from the shoulder to the elbow. Immovable dressings are also in quite common use, and may be used with confidence whenever displacement is absent or slight. Dr. Allis maintains that the posterior splint is to be rejected, because the turns of the bandage which is used to bind the forearm to the splint force the radius and the attached condyle downward and thus destroy the outward angle of the forearm, but the objection is more easily met by the use of a moulded splint and loosely applied bandage than by treatment in the extended position, as he proposes. It will be found in practice that in some cases the flexed position and in others the extended position favors displacement of the radius, and the treatment must be varied accordingly.

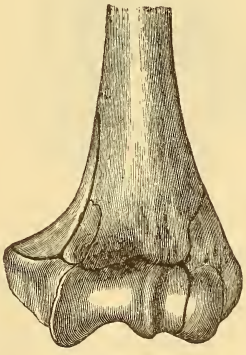
6. Intercondyloid Fractures.—In the simplest form of this variety the line of fracture is in the form of a T or Y, the vertical branch extending into the joint, the other crossing the shaft more or less directly a short distance above. Sometimes the transverse line lies just above the articular surface and is quite irregular in its direction, or the fracture may be comminuted. These varieties are represented in the annexed figures.

Fig. 219.



Intercondyloid fracture of the humerus.

Fig. 220.

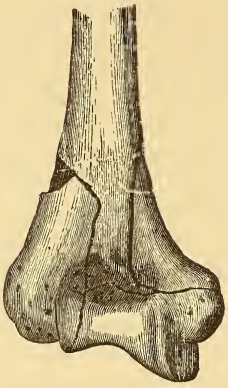


Intercondyloid fracture of the humerus. Front view. (Gurlt.)

The fracture is not a very common one, and in almost every recorded case appears to have been produced by direct violence, a fall or a blow

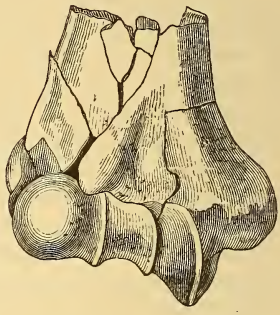
upon the elbow. The most frequent form of displacement is the lateral separation of the condyles and their ascent in front or on either side of

Fig. 221.



Intercondyloid fracture of the humerus. Rear view. (Gurlt.)

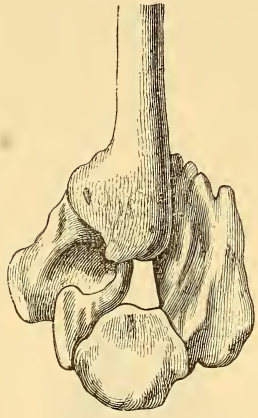
Fig. 222.



Comminuted intercondyloid fracture of the humerus. (Gurlt.)

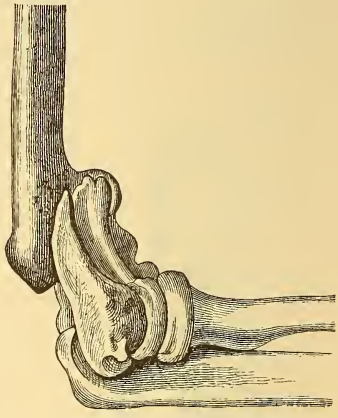
the shaft, bringing the end of the latter near the olecranon (figs. 223, and 224).

Fig. 223.



Intercondyloid fracture of the humerus; separation and ascent of the condyles; seen from behind.

Fig. 224.



The same, seen from the outer side. (Gurlt.)

The fracture is frequently compound, and the soft parts badly lacerated; and in one case in which the end of the upper fragment had perforated the skin and projected for the distance of an inch the median nerve had been pushed before it and was tightly stretched over its edge. In other cases the brachial artery has been compressed or torn. The cause of the displacement in the first place is usually the violence which produces the fracture, it is received upon the under side of the olecranon

and forces the latter up like a wedge between the condyles; but the reproduction or the persistence of the displacement is in great part the result of the contraction of the triceps, biceps, and brachialis anticus.

Marked deformity, involving the entire region of the elbow and sometimes sufficient in itself to establish the diagnosis, is a prominent symptom, and with it are found extensive changes in the three prominences of the epicondyles and the olecranon, crepitation, and abnormal mobility. Perhaps, the most striking element in the deformity is the increase of the transverse diameter of the humerus at the condyles; if this is very great and the olecranon has been forced up between the condyles it may be impossible to obtain crepitation until after the olecranon has been drawn down and the condyles pressed together. The direct violence, which, as has been said, is the common, if not the only cause of the injury, leaves its marks upon the soft parts, and the fracture is frequently compound. If the wound is large enough to permit exploration with the finger the details can usually be made out satisfactorily.

If the fracture is simple and without such bruising of the soft parts as may require special treatment to prevent or diminish inflammation, the arm may be placed in a moulded posterior splint, or in an immovable dressing after reduction of the displacement. The future usefulness of the limb requires reduction of the displacement not only to restore the mechanical conditions of the joint, but also to keep the inflammatory reaction within the narrowest bounds, for fibrous ankylosis is the consequence of the processes accompanying the latter. In my judgment early passive motion is not to be thought of in these cases, and the surgeon's efforts must be directed to maintaining reduction and keeping down inflammation. Unfortunately it is not easy to combine the measures appropriate to the two indications; the rest, quiet, and pressure which are so suitable to the second are not entirely compatible with the frequent inspection that is necessary to protect against the tendency to displacement. The plan that seems most suitable, one that as I write has just yielded me a very good result, is to place the limb, flexed nearly to a right angle, in a gypsum posterior splint moulded to it while extension and coaptation are made; then to apply a similar anterior splint over a thick layer of cotton, bind the two together, and make continuous extension for a time from the forearm close by the elbow by means of India-rubber or a weight.

After three or four weeks the arm may be left loose in the posterior splint or even suspended in a sling, and the range of motion forcibly but cautiously increased once or twice a day if the attempt does not cause persistent pain in the joint. In this way projecting fragments that would otherwise limit the range may be pressed out of the way and soft adhesions broken or stretched. It is especially desirable that flexion to within a right angle should be made possible.

In the more severe cases the surgeon may have to content himself with merely supporting and immobilizing the limb upon a splint or cushions after incomplete reduction while awaiting the subsidence of the swelling.

In compound fractures the rule is well established to excise so much of the shaft as is necessary to make reduction and retention easy, and

often it is desirable to remove the condyles also, in short to do a partial excision. I have spoken elsewhere of the change in the treatment of articular fractures brought about by the introduction of the antiseptic method, of the expectative treatment which it justifies, and of its removal of the necessity for the so-called "preventive resections," those which were undertaken to prevent violent inflammation of the joint and retention of the pus, but it must be remembered that the conditions at the elbow are not quite the same as at other joints and that it is often better to try there for a movable joint, even if it should be abnormally loose, than for ankylosis. In young people, especially, whose power to reproduce bone is great, an elbow after excision is, as a rule, very serviceable, and is often almost as much so as its uninjured fellow. For this reason and the additional one that the joint is especially difficult to drain and that the usefulness of the hand may be greatly diminished by the burrowing of pus and the formation of abscesses among the muscles of the forearm, a primary removal of the condyles is sometimes to be preferred to pure conservative or expectative treatment. It is worthy of note that the records show better results, so far as the mobility of the joint is concerned, after compound fracture with resection than after simple fracture.

I have been led to think, after the experience of some resections in adults, that it is best to make the excision semi-articular in such cases (adults), to leave the radius and ulna untouched. While it is probable that the mobility of the new joint will be less after such an operation than after a total excision, it will still be sufficiently free, and the preservation of the olecranon adds greatly to the efficiency of the triceps.

The following case is quoted from Mr. Cheyne's statistics of Mr. Lister's practice[1] in illustration of this principle.

The patient, a boy 12 years old, was admitted on account of a badly united fracture of the lower end of the humerus with dislocation of both bones of the forearm backward. The accident happened three months before admission; the movements of the joint were very limited.

"On the supposition that the case was simply one of fracture, a longitudinal incision was made behind the joint with the intention of excising it; but the true nature of the case being revealed, it was determined to avoid interference with the bones of the forearm. A small slice was sawn away from the lower end of the humerus, which was greatly distorted and thickened by callus. The lower end of the humerus was then pared and shaped with chisel and gouge, so as to resemble the natural form of the articular end of the bone, hollows being gouged for the reception of the olecranon and coronoid processes. The dislocation was then reduced; drainage tubes inserted, and wound stitched. The reason for preferring this operation to complete excision was to avoid the lagging behind in growth of the forearm and hand, which is so apt to occur after that operation in young children.

"Aseptic course. Passive motion begun on the day after the operation. Pronation and supination were perfect from the first and always continued so. The limb was very strong. The movements of flexion

[1] Brit. Med. Journal, Nov. 29, 1879, p. 1862, Case 18.

and extension were fair and were constantly improving when the patient was discharged [five months afterwards]."

The following cases are quoted in illustration of the course, treatment, and result under varying conditions :—

1.[1] A woman, 44 years old, fell upon the sidewalk striking upon her right elbow ; when seen a few minutes afterwards, the parts were already much swollen ; the forearm was slightly flexed and pronated. On seizing the elbow firmly distinct motion could be felt above the condyles, also crepitus, and also the point of the upper fragment indistinctly. While moderate extension was made the condyles were pressed together and it then became apparent that they had been separated. On removing the extension, they again separated and the olecranon drew up. The patient was in a condition of extreme exhaustion, and the bones were easily placed in position. An angular splint was secured to the limb, and every care used to support the fragments completely but gently. The dressings were frequently removed and the elbow moved as much as it was possibly to move it. Seven months afterwards, the elbow was almost completely ankylosed, and the fingers and wrist were quite rigid. Six years later the ankylosis had nearly disappeared.

2. H. W——, 43, a large healthy man, was admitted to Bellevue Hospital, January 5, 1881. Shortly before, while walking, he had slipped and fallen, striking only upon the palm of his right hand. I saw him the next morning, found the right elbow much swollen, and recognized an intercondyloid fracture of the humerus, probably Y-shaped. Each condyle could be moved separately with crepitation, the upper edge of each fragment could be distinctly felt on the condyloid ridge, and the end of the upper fragment could be felt indistinctly in the bend of the elbow, where pressure caused much pain. There was an increase in the breadth of the lower end of the humerus, estimated at half an inch.

He was kept in bed with hot applications upon the elbow, and the limb supported upon cushions for two days, and then, the swelling having subsided, moulded posterior and anterior splints were applied, the elbow being flexed nearly to a right angle. During the hardening of the splints extension was made by drawing upon the forearm near the elbow, and lateral pressure upon the condyles by grasping them with one hand. Continuous extension by weight and pulley was kept up for several days, during which the patient remained in bed.

31st January. The anterior splint was removed, and the arm left loose in the posterior one, and supported in a sling; two or three days afterwards the posterior splint was removed and the patient directed to carry the arm in the sling. Motion at the elbow was free and painless through a range of about 45°, from 100° to 145°. Feb. 4th, 6th, and 8th, I forced it gently, carrying flexion to about 80°. Pronation and supination were almost complete ; patient discarded the sling and used the arm freely in carrying small objects. Left hospital Feb. 10th.

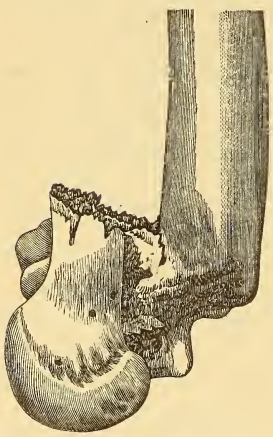
3.[2] A healthy man 34 years old had his right elbow crushed by the

[1] Hamilton, loc. cit., p. 280.

[2] Jonathan Hutchinson, Med. Times and Gazette, 1866, vol. i. p. 516.

fall upon it of a heavy chest. The skin was considerably contused, and there was a small laceration on the inner side of the joint. We were not certain that this communicated with the joint, but on the next day the discharge of synovia-like fluid made this almost conclusive. The limb was got into good position, placed on an angular splint, and surrounded by bladders of ice. During the next fortnight the ice treatment was carefully and efficiently carried out. It did not, however, suffice to prevent a most acute attack of traumatic synovitis; there was much swelling and several abscesses. The suppuration was profuse, and fearing the man's health would give way excision was recommended on the sixth week. The patient died during the preliminary administration of chloroform. The fracture was Y-shaped, and partial union had taken place. Figure 225 represents the specimen and is a significant commentary upon the statement that the limb was got into good position.

Fig. 225.



Displacement forward of lower fragments after intercondyloid fracture of the humerus.

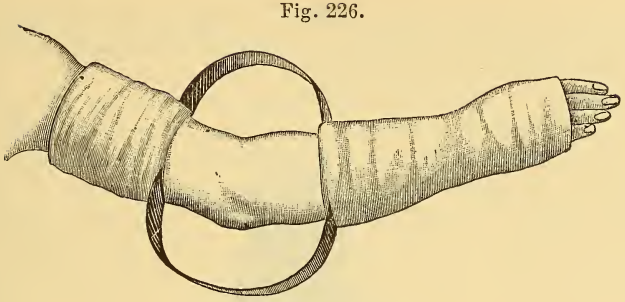
4.[1] A publican, aged about 50, accustomed to a very free mode of life, fell from some steps and sustained a compound fracture of the left elbow, the inner extremity of the upper fragment perforating the skin, and synovia escaping from the wound. The soft parts were much bruised. Complete excision of the ends of the three bones was done in the usual manner through a T-shaped incision. The arm was much swollen during the first three weeks, there was a slight attack of erysipelas, and some delirium, "probably a complication of delirium tremens and the traumatic form." The wound healed and he left the hospital at the end of seven weeks. He was seen repeatedly afterwards, was in excellent health, and had good use of the arm, which he could flex and extend through a wide range.

4.[2] George G., 60, admitted June 28, 1872, two and a half hours after the accident, with a compound comminuted fracture of the humerus caused by the passage of the wheel of a wagon over his arm. Humerus fractured in two places, the lower fracture communicating with the elbow-joint. The wound was injected with 1 to 20 carbolic lotion; some loose pieces of bone removed from the lower wound. Tpyical aseptic course. The fracture had quite united on August 10th. The wound was quite superficial on August 31 and boracic dressing was applied. Erysipelas August 15th. Wounds healed September 20th. When dismissed the patient was able to flex his arm sufficiently to touch his opposite shoulder.

Interrupted dressings of plaster (fig. 226) or some one of the special forms of splints, suspended or otherwise, so constructed as to permit the

[1] Hutchinson, loc. cit.
[2] Cheyne, Brit. Med. Journ., 1879, vol. ii. p. 863, Case 22.

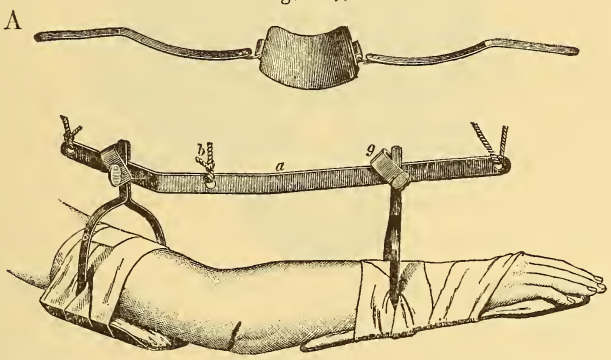
Fig. 226.



Interrupted plaster splint.

dressings of the wound to be changed without the removal of the splint (fig. 227) should be used in the compound fractures.

Fig. 227.

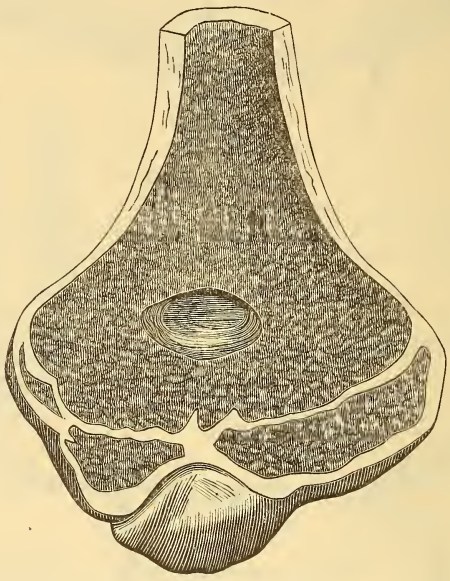


Esmarch's interrupted splint. A is to be placed outside the dressing.

7. Separation of the Epiphysis.—The epiphysis, which includes both epicondyles, grows relatively smaller as the individual advances in years; it shows at first five separate centres of ossification, which are reduced to three some time before fusion with the shaft takes place. Figure 228 represents the direction of the lines at the age of fifteen years; the small piece on the side is the internal epicondyle. The figure represents the section as seen from behind and shows the centre of the olecranon fossa. In consequence of the smallness of the epiphysis and its protected position its separation is a rare accident and one that has been rarely demonstrated by direct examination. Gurlt (loc. cit., vol. i. p. 82) quotes the description of a case observed in 1818; Mr. Hutchinson (*Med. Times and Gaz.*, 1866, i. p. 360) describes another, and Dr. Hamilton (loc. cit., p. 272) describes and figures a third and gives a figure of a specimen from a fourth that was presented to the N. Y. Surgical Society by Dr. Lange in 1880. There is also a specimen in the Museum of Bellevue Hospital, the bones of the forearm of a child with a shrunken cartilage attached which seems to be the lower epiphysis of the humerus. In the first and third cases amputation was done, in the second the end of the upper fragment which projected was excised and the patient recovered with a stiff elbow, and in

the fourth the epiphysis was removed through the wound and a portion of the shaft excised, the patient made a good recovery and had a useful arm with free flexion and extension.

Fig. 228.



Epiphyseal lines at the lower end of the humerus in a boy fifteen years old. (Hutchinson.)

Mr. Hutchison thinks he has seen "half a dozen recent examples of this form of injury and at least twice as many old ones in which advice was sought in consequence of the awkward deformity which often follows it." He describes the symptoms as like those of a dislocation backward; conspicuous deformity, the end of the elbow projects, the tendon of the triceps is prominent and curved, and the forearm looks shortened. The diagnosis is made by observing that the relation between the olecranon and the epicondyles and the position of the head of the radius are not changed. The forearm is also freely movable upon the arm, and if the deformity is reduced crepitus can generally be felt. In the displacement the lower fragment is carried bodily backward with the bones of the forearm, which preserve their relations to it, and, according to Mr. Hutchinson, is rotated inward so that its inner extremity is prominent under the skin.

The indications for treatment are essentially the same as in fracture above the condyles; to prevent bodily displacement of the fragment backward or an angular displacement that would cause the vertical axis of the fragment to incline forward and upward. This latter displacement is favored by the contraction of the flexor muscles of the forearm, and it is with the view of preventing it especially that Mr. Hutchinson recommends treatment by extreme flexion of the forearm upon the arm. He admits "that it is difficult, if not impossible, to effect accurate coaptation of the fragments [either in separation of the epiphysis or in fracture

above the condyles]. There is almost certain to be some overlapping, but still the bent position is the best one."

8. Fracture of the Articular Process.—The existence of this variety, which appears to have been first described by Laugier,[1] who made the diagnosis during life of a fracture of the trochlea alone, but did not verify it by dissection, has been since demonstrated anatomically. Gurlt quotes the descriptions of two specimens, one of which shows fracture of the entire articular process, the other of the portion corresponding to the head of the radius. The first is the right humerus of an adult; the trochlea and capitellum have been broken off and displaced forward and upward, and have reunited firmly with the bone above the coronoid fossa. The articular surface is still covered with cartilage; the radius and ulna are lacking.

The other specimen was taken from a woman sixty-seven years old who, four years previously, had hurt her elbow while intoxicated. On examination after the swelling had subsided, a hard round prominence was found in front of the external condyle which did not move when the wrist was rotated, and pressure upon which produced crepitus. The diagnosis of fracture of the neck of the radius was made, but on the death of the patient four years afterwards the capitellum was found broken from the condyle and trochlea, displaced forward and upward, and reunited with its upper border lying in the radial depression (fovea anterior minor). The head of the radius lay below in the cavity left by its removal. The olecranon and coronoid fossæ were filled up with new deposits of bone.

The only other case of which a clinical description is given is Laugier's, a supposed fracture of the trochlea alone, and although the diagnosis is not entirely free from doubt I subjoin an abstract of the history. The patient was a girl, seventeen years old, who had fallen upon her hand. The region of the elbow was not swollen, its voluntary movements painful, range of passive movements complete. Crepitation was produced within the joint by rotating the wrist, and much more clearly by extending the forearm completely and then bending it toward the inner side. When completely extended the forearm showed a slight abnormal inclination to the inner side which could be diminished by pressure. No change in the epicondyles. The diagnosis of fracture of the trochlea was made upon this abnormal mobility with crepitation and the integrity of all accessible bony points. The treatment was rest with the forearm half flexed and pronated. Recovery took place in a few weeks without loss or diminution of function. There was at no time any appearance of effusion within the joint.

Laugier lays down seven propositions as characteristic of this variety of fracture, but as they merely restate the symptoms given above they do not need repetition here.

9. Simultaneous Fracture of the Humerus and the upper end of the Radius and Ulna.—This variety deserves the separate classification which it sometimes receives, mainly because of the emphasis which

[1] Archives Générales de Méd., 1853, vol. i. p. 45.

may thus be given to the promise held out by conservative treatment. The injury is a severe one, usually caused by direct violence, and usually compound. The fracture of the humerus may be articular or extra-articular; of the other two bones the ulna is the one most frequently broken. The details of the fracture and of the symptoms are too diverse for classification. The fact to be borne in mind is that even under former and less favorable methods of treating wounds, both life and limb were habitually saved by excision of the joint, and that under modern methods of treatment we have a right to expect to obtain a good result even more frequently and more easily.

DIAGNOSIS.

In the examination of an injured elbow the first point to which the surgeon's attention should be directed is the relations between the four principal bony prominences, the two epicondyles, the tip of the olecranon, and the head of the radius. If these points can be recognized by the finger the existence of any displacement or of a dislocation ought not to escape detection. The thumb and middle finger should be placed upon the tips of the condyles, and the index finger upon the tip of the olecranon. When the forearm is extended these three points are normally in the same horizontal line, and when the forearm is flexed the olecranon lies below a line drawn from one epicondyle to the other. The head of the radius lies normally about half an inch below the external epicondyle, and when its shaft is not broken it can be felt to move as the wrist is rotated.

Measurement of the arm from the acromion to the external condyle, and from the latter point to the wrist, and of the transverse diameter at the condyles, sometimes gives valuable information. The following is a brief recapitulation of the signs by which the more important of the different fractures are to be recognized, and those of dislocation of the forearm backward are added for the sake of comparison.

Fracture above the Condyles.—Usually the olecranon projects and the tendon of the triceps curves backward, and this projection is increased by straightening the forearm upon the arm. The normal relations of the olecranon and epicondyles are preserved; there is abnormal mobility above the joint with crepitus. Disappearance of the deformity when traction is made upon the forearm, and its prompt reappearance when the traction is intermitted. Free and painless mobility of the joint.

In the rarer cases of displacement of the fragment forward the resemblance to a dislocation backward is lost.

Dislocation of the Radius and Ulna Backward.—The olecranon projects and the tendon of the triceps is curved, but the projection is diminished by straightening the forearm upon the arm, and the tip of the olecranon at the same time rises above the line drawn between the two epicondyles. Loss of normal relations between the olecranon and the epicondyles. The head of the radius is displaced backward. If the deformity is reduced by traction upon the forearm it usually does not recur. Forearm slightly flexed upon the arm and almost immovable; some lateral mobility.

Fracture of the Internal Condyle.—Change in the relations of the

epicondyles if there is displacement. Crepitus and abnormal mobility recognized by grasping the condyle with the thumb and fingers and moving it upon the humerus, or by grasping the elbow with one hand and moving the forearm laterally with the other. The condyle remains attached to the ulna, and moves with it. Abnormal lateral mobility of the forearm when completely extended.

When complicated by dislocation backward the head of the radius is found below and behind the external condyle, and if the finger is passed down along the internal condyloid ridge of the humerus it recognizes its abrupt termination at the line of fracture.

Fracture of the External Condyle.—Crepitus and abnormal mobility recognized by manipulation of the condyle or lateral movement of the forearm. Change in the relations of the condyle with the olecranon and internal condyle, preservation of its relations with the head of the radius. The latter sign is of especial value in those cases in which the bones of the forearm are displaced outward and backward, and in which the diagnosis is very obscure. The examination should be repeated after the dislocation has been reduced.

Intercondyloid Fracture.—Marked deformity consisting in increase of the breadth of the humerus at the condyles, often shortening of the arm; marked change in the relations of the bony prominences; independent mobility of each condyle upon the shaft and upon each other; crepitation, which, however, may not be obtained until after the forearm has been drawn forcibly downward and the condyles pressed together. Comminution may, perhaps, be recognized by the freer crepitation and abnormal mobility.

TREATMENT.

The methods of treatment suitable to the different varieties have been mentioned in connection with each. The violence of the reaction may call at first for measures to reduce the inflammation, and some surgeons prefer to postpone the application of splints until the swelling has subsided, placing the limb meanwhile upon pillows. Others apply a well-padded temporary splint to prevent motion of the fragments by muscular twitching or accidental change of posture. Hot applications, or lead and opium, or evaporating lotions are applied to the elbow, and leeches are sometimes used. In a few cases I have been much pleased with the benefit derived from a rubber bandage covering the hand, forearm, and half the arm. Used immediately after the injury it has prevented pain and swelling, and at a later period it has rapidly reduced the latter. It should be applied rather loosely at first, watched closely, and tightened or loosened as circumstances may indicate.

Some surgeons first apply a roller bandage from the hand to the axilla to prevent spasm and limit the swelling, but the practice is dangerous. There is, perhaps, no risk in placing the bandage upon the hand and forearm, but it should not be carried above the fracture.

The best moulded posterior splint, when it is designed to hold the fragments closely, is one of gypsum, and an elegant finish can be given to it by placing a thin layer of sheet lint between it and the skin. If the tendency to displacement is slight, if the parts have been bruised and swelling is anticipated, a layer of cotton may first be placed upon

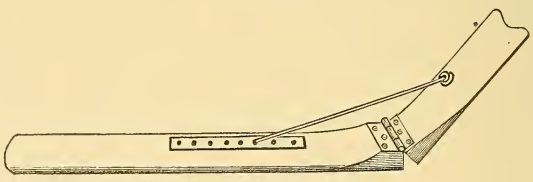
the limb, then the posterior splint fitted, and a roller bandage placed snugly over all; a similar anterior splint is sometimes needed in addition.

A convenient splint that allows easy inspection is the one recommended by Dr. Allis, and described in the section on fractures of the internal condyle, or a similar one made with dextrine or silicate of soda; that is, a layer of cotton about the limb from hand to shoulder, bound down and covered in with a roller bandage stiffened with the white of egg. Retention of the fragments is aided by longitudinal strips of adhesive plaster upon the skin. This is sufficiently firm to keep the limb in the position selected, and if split longitudinally it can be easily sprung off without affecting its shape. It does not control the fragments directly, and cannot therefore be depended upon to prevent displacement if there is any active agency present to cause it; it acts only by keeping the limb in the selected position, and at the same time allows inspection.

The position in which the elbow is midway between a right angle and complete extension, or even a little nearer the latter, is to be recommended in most cases; the exceptions are fractures of the epicondyles, of the internal condyle with dislocation backward, and, perhaps, also of the external condyle. Berthomier[1] found by experiment upon the cadaver that the position of extension was more favorable than flexion to accurate coaptation of the fragments in all fractures except those of the epicondyles and external condyle, and recommended it as the habitual position for treatment. The question cannot be decided by cadaveric treatment, because this leaves out the highly important element of muscular contraction, but the practice is certainly gaining clinical support.

An anterior splint (fig. 229) is employed by some in preference to a posterior one. It is usually made of wood with a fixed angle or a hinge

Fig. 229.



Anterior splint.

that permits the angle to be changed, and is fastened to the arm with a roller bandage, a layer of cotton or a compress being interposed between it and the skin.

I have already expressed my opinion concerning the value of passive motion. I believe that employed with vigor, at any time during the first three weeks, it is more likely to do harm than good. I do not believe it is proper during this period to move the limb in such a manner as to cause pain. I have seen an elbow stiffen rapidly, and a range of motion of more than 90° lost entirely within a week under this practice. But there is no objection to changing the position in which the limb is kept, even daily, after the first week or two, and that can be conven-

[1] Fractures du Conde chez les Enfants, Thèse de Paris, 1875.

iently done by means of the anterior hinged splint. At each dressing the angle is changed a few degrees. If the surgeon wishes to make passive motion he should support the elbow by grasping it firmly with one hand, while he carefully extends and flexes the forearm with the other.

Even under the most favorable circumstances the joint will be more or less stiff when the splints are first removed, and the tissues about it will be more or less swollen and indurated. The latter condition is readily corrected by rubbing and by the temporary use of a rubber bandage; and the first will ordinarily disappear rapidly as the arm is used. The exceptions are the cases in which the form of the joint has been materially changed, in which a mechanical obstacle to flexion or extension is presented by a displaced fragment or by an overgrowth of callus, and those in which the severity or the duration of the inflammation has resulted in a permanent retraction and thickening of the capsule and periarticular tissues.

Constant and rather forcible use of the arm will increase the range of motion rapidly, especially in the direction of flexion, an additional reason for dressing the limb in the extended position. I have often heard a friend, a skilful and experienced surgeon, speak with much satisfaction of the rapidity with which in one case an elbow, stiffened after fracture, regained its mobility under his observation. The patient was a young lad, and the stiffness had resisted forcible attempts at passive motion made almost daily for some time. My friend advised the parents to give the boy a boat and let him spend his time upon the water. Nothing was done to the elbow, but within two months it had recovered its full range of motion.

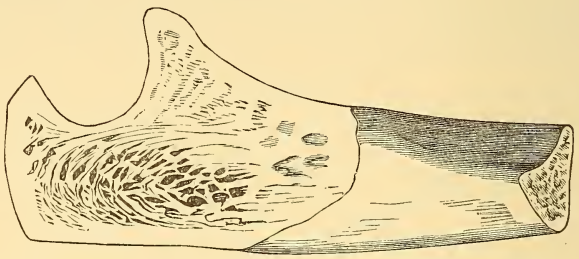
CHAPTER XXII.

FRACTURES OF THE BONES OF THE FOREARM.

A. In the Vicinity of the Elbow-Joint.

1. Fracture of the Olecranon.—The frequency of fractures of the olecranon has been very differently estimated by different writers, Malgaigne placing it among the rarest, only 9 cases in a total of more than 2300 fractures treated during eleven years at the Hôtel Dieu, while in the tables given in Chapters I. and IX. it rises to 3 per cent. The personal experience of individual surgeons seems to differ even more widely; Hoin, according to Malgaigne, saw only one case during thirty years of hospital service at Dijon, Camper two, and Malgaigne six; while, on the other hand, Hamilton says his records contain accounts of seventeen cases. I have seen four in three years, and five cases were admitted during a single year into one division of Bellevue Hospital.

Fig. 230.



The olecranon, divided vertically.

The most common cause is a fall or blow upon the elbow. Muscular effort, contraction of the triceps, appears to be an occasional cause, and it has been recently alleged that a blow upon the ulna near the elbow can break or crack the olecranon from the articular surface outwards. The position of the fracture varies apparently with the cause; it may lie close to and parallel with the upper end of the process, or at any intermediate point above the base of the coronoid process crossing the bone transversely or obliquely, or along a V-shaped line corresponding somewhat to the borders of the triangular subcutaneous surface of the olecranon. In rare cases it is comminuted, and sometimes is compound.

The commonest cause by far, in 36 out of 45 cases collected by one writer, is a fall upon the elbow. The mechanism, however, is not simply that of fracture by direct violence, the bone is not broken by

a force acting directly upon the end of the apophysis, but the contraction of the triceps must play an important part in it. Among the reasons for this belief are the usual absence of the signs of direct violence upon the surface of the region sufficient to have caused the fracture, and the impossibility of producing similar fractures upon the cadaver by this means. When the fracture is produced experimentally by direct violence, by a blow with a blunt object, the bone is not broken cleanly and transversely at its narrowest part, as is the case in most fractures observed clinically, but it is crushed and split into several pieces. The explanation that seems most plausible is that a sudden change is effected in the position of the forearm by the fall when the muscles are all tense. The man falls with his elbow partly bent, and all his muscles rigid with the effort to save himself; his outstretched hand, or the back of his forearm encounters some solid object, and the flexion of the limb is suddenly and violently increased, while the olecranon is held immovable by the triceps. The consequence is that the ulna is bent about the elbow, and breaks at the weakest part of the olecranon if the violence is received near the elbow, or, perhaps, at some part of its much thinner shaft if the violence is received upon the hand; in short, the bone is broken across the elbow as a stick is broken across the knee.

In a few cases the olecranon has been broken in an attempt to reduce an old dislocation; in others it has been broken at the same time that dislocation took place backward or forward. I saw it broken once in an attempt to flex a stiff elbow; and Malgaigne (loc. cit., vol. ii. p. 575) quotes a very singular case of fracture, in part at least, by muscular action: A man twenty-one years old, who had shown a marked disposition to fracture in youth, was carrying a heavy pitcher of water in his hand. He felt pain in the elbow, which increased gradually and then suddenly became sharp, with a cracking sound. There was found a transverse fracture of the olecranon with a complete dislocation backward that could not be reduced.

Fracture by muscular action is rare. Malgaigne examined critically five cases reported as such, and rejected two of them as at least doubtful. The three which he accepted as actual examples of fracture by muscular action were reported by Capioment, Richerand, and Blandin. In the first the patient was left alone to hold a capstan, and while making a vigorous effort to keep it from turning back, felt something crack in his elbow, and at once lost power in the arm. The olecranon was found to be broken. In the second the fracture was caused by an effort to throw a ball, and in the third by extending the arm in diving. To these Malgaigne adds a fourth, observed by himself, but it is one which perhaps should be explained rather by the mechanism described in the last paragraph but one: a man thirty years old, playing with a comrade, had his forearm suddenly and forcibly flexed upon his arm while resisting; he felt a sharp pricking pain, but returned to his work; flexion became more and more painful; he consulted a surgeon, and the apex of the olecranon was found to have been torn off. Monteggia tells of a woman who broke her olecranon by striking her maid.

In fractures due solely to muscular action the fragment torn off is small, little more than the cortical layer of the summit of the process to

which the triceps is principally attached; in other cases the line of fracture lies usually at the narrowest part of the process, directly under the centre of the sigmoid fossa, that which is called by some the centre, by others the base of the olecranon.

Another variety of fracture, partial or complete, and produced from within outwards, has been spoken of by different writers as theoretically possible, but has only recently been observed and described clinically. Pingaud[1] produced it experimentally in the effort to dislocate the ulna backward by over-extension (extension beyond the straight line) of the forearm. The end of the olecranon is pressed against the humerus, the lateral ligaments resist the movement, and the prolongation of the effort results in fracture of the olecranon or, much more commonly, of the thinner and weaker shaft of the ulna. Quintin[2] reports three cases of incomplete fracture of the olecranon; the surface articulating with the humerus was broken, the dorsal portion was unbroken; in all the swelling was moderate, the pain severe, flexion and extension complete but slow. In the first case, seen a week after the accident, a small prominence could be felt on the side of the olecranon, and behind it was a notch; the upper end could be sprung back a little. In the second case a short shallow groove could be felt on the outer side of the olecranon, at its base; and in the third the olecranon could also be sprung. Quintin thinks this fracture is frequently overlooked and treated as a simple contusion. The symptoms in the three cases described will, perhaps, hardly be considered entirely demonstrative in the absence of corroborative testimony, of direct examination of a recent fracture; and, indeed, it is only by admitting that the injury is a common one and has heretofore always been overlooked, that its occurrence three times during a short period in the experience of one observer can seem probable. Corroborative testimony is said to be furnished by experiments upon the cadaver made by Madelung and Lesser, who found that when the blow fell directly upon the olecranon, the forearm being partly flexed, the result was a fracture of the olecranon from without inward (from the dorsum towards the articular surface), the end of the process being bent into the olecranon fossa; while if the violence was distributed more widely upon the upper third of the forearm, the result was either fracture of a condyle, T-shaped fracture of the humerus, or fracture of the olecranon in the opposite manner, from within outward, its apex being bent away from the fossa instead of toward it. I fail to understand the mechanism as it is described, and confine myself, therefore, to this brief restatement of the author's views.

Symptoms.—The symptoms of the fracture are pain, swelling, displacement, and mobility of the upper fragment, sometimes crepitation, and loss of power, especially of active extension. Some of these symptoms require more detailed notice.

As the result, apparently, of theoretical considerations, and of what has been observed in exceptional cases, the tendency to displacement upward of the fragment by the contraction of the triceps has been some-

[1] Dict. Encyclopédique, art. Coude, pp. 517 and 631.

[2] Beitrag zur Lehre von den Brüchen des Olekranon, Bonn, 1881, Abstract in Centralblatt für Chirurgie, 1881, p. 763.

what overstated. This action of the muscle is greatly restricted by the lateral aponeurotic attachments and ligaments, and by the extension of the insertion of the triceps along the lateral and posterior aspects of the olecranon, all of which must be ruptured before the fragments can be widely separated and the upper one drawn high up. In a discussion in the Société de Chirurgie[1] which followed the presentation by Bardinet of a paper upon this subject, Robert, Richet, and Gosselin testified to the usual absence of separation in their experience, and similar testimony has been since furnished in abundance.

If the thick periosteum and tendinous attachments on the sides and back of the olecranon are torn, nothing remains to hold the fragments together, and separation may be effected either by the contraction of the triceps, drawing the upper fragment away from the shaft of the bone, or by the flexion of the forearm, drawing the bone away from the fragment. In either case coaptation is effected by extending, straightening, the forearm upon the arm, because the triceps cannot draw the fragment above the position which it takes in complete extension unless the ligaments which bind it to the humerus are torn, and this is a complication which apparently happens very rarely. Some authors speak of a separation of one or two finger-breadths and even of one or two inches, but do not indicate the position of the joint at the time the measurement was taken. In a case dissected and pictured by Sir Astley Cooper[2] he says: "the olecranon is separated two inches from the ulna; the capsular ligament of the elbow-joint is torn through on each side of the olecranon; and the separated portion is united by a ligamentous band which is stretched from one broken extremity of the bone to the other." The accompanying drawing represents the elbow flexed at a right angle and the olecranon just behind its own fossa, so that it seems probable that the separation would be much less if the forearm were extended. Such a degree of separation is entirely exceptional, and even in cases in which reunion of the fragments has failed, the upper one has not risen above the olecranon fossa. It may also happen that a separation which is slight at first may be afterwards increased by forcible flexion of the arm or by a voluntary effort to extend it.

Another displacement, one that is important because of the danger that the skin may be broken by the pressure which it leads to, is an angular one observed in a few cases when the line of fracture has been near the base of the coronoid process, and especially when its direction has been obliquely downward and backward and the upper fragment has ended in a sharp lower edge or point. In the discussion in the Société de Chirurgie above referred to, Robert mentioned a case of this kind in which perforation occurred after about two weeks. Robert, who was at the time Dupuytren's interne at the Hôtel Dieu, admitted the patient, who had been severely injured in other ways, recognized the fracture of the olecranon, and dressed the limb in the extended position. A few days afterwards Dupuytren removed the dressing, found no displacement, and, apparently doubting the diagnosis, left the limb without splints. No attention was paid to it until ten days afterwards when

[1] Bulletins de la Soc. de Chirurgie, vol. vi., 1856, p. 152.
[2] Dislocations and Fractures, Am. ed., 1851, p. 413, Case 238.

perforation was found to have occurred. Richet spoke of a similar case in his own practice, but the report of his remarks leaves it uncertain whether the perforation was due to pressure or to the formation of a large abscess. Gosselin had a case in which the displacement was irreducible.

Mobility of the fragment is recognized by grasping it between the thumb and finger and moving it laterally, or by flexing the forearm gently while the finger is pressed against the groove or crack left by the separation when it is slight. If the fragments are brought together by extending the forearm or drawing the upper fragment down, crepitation can be felt.

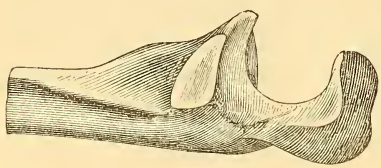
If the swelling is sufficient to prevent recognition of these objective signs, the fracture may be suspected from the history of the case and the loss or marked diminution of the power of active extension.

In a case of compound fracture observed by Rey,[1] the surface wound being a small one over the posterior aspect of the olecranon, air entered the joint with a whistling sound when the elbow was flexed and came out in bubbles when it was extended. There was no displacement of the fragment, and the patient made a good recovery with bony union and slight limitation of motion.

Repair.—It is very important, with reference both to treatment and prognosis, that the character and extent of the displacement should be known. As a rule, union takes place, but it is fibrous, not bony; and the restoration of function depends in a measure upon the length of the fibrous band. I say "in a measure," for experience has shown in not a few cases that there may be excellent control over the limb even with a long fibrous band between the two fragments. The disability sometimes observed under the opposing conditions, limitation of motion when the band is short, is due to adhesions between the fragment and the humerus, or to change in the flexibility and length of the capsular bands. The process of repair involves two dangers: defective union or failure of union between the fragments, and the formation of intra-articular bands or changes in the articular and peri-articular tissues.

Instances of bony union do exist. Malgaigne figures and describes one in his Atlas (Pl. XXIV., fig. 2), which, however, differs notably from the ordinary fracture, the line having run so obliquely as to bring away with the olecranon a lateral half of the coronoid process. Many instances of union with very slight separation, if any, and apparently bony, have been reported, but in only a few has the character of the union been established by autopsy. Gurlt[2] describes and pictures two: one, a fracture half an inch from the apex of the process, united with slight displacement of the fragment upward and only a small amount of callus on the outer side; the line of fracture is partly visible upon the surface of section, and complete extension of the joint is prevented by an overgrowth of bone at the apex.

Fig. 231.



Fracture of olecranon; bony union. (Gurlt.)

[1] Union Médicale, 1873, vol. xv. p. 208.
[2] Loc. cit., vol. i. p. 41, fig. 9, and p. 310, fig. 121.

The other is an oblique fracture (fig. 231), and has united so completely that the only sign of it is "a shallow groove on the under surface of the olecranon running obliquely backward from the radial to the ulnar side. The articular cartilage is lacking in part, and the callus consequently visible."

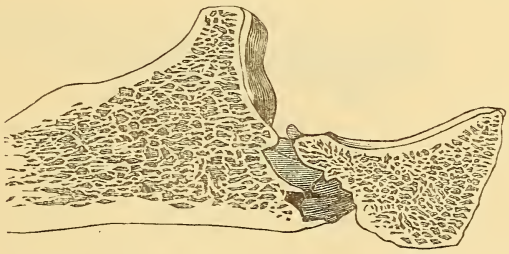
Mr. Fletcher,[1] of Liverpool, reported a case of bony union of both olecranons, verified by examination after death. The patient, a boy 16 years old, was admitted to the hospital May 19, 1850, having fractured both olecranons a short time before by falling over some timber. There was separation to the extent of a finger's breadth. The fractures were treated with the arm in the extended position "for the usual time," the stiffness was then gradually overcome by passive motion, and the patient was discharged July 21. He was re-admitted in the following January, having full use of both arms, and died of phthisis March 9th.

Full osseous union was found. The signs of fracture were an irregular furrow on the surface of each sigmoid cavity two lines wide, along which the articular cartilage was entirely wanting. On the right olecranon this furrow was three-eighths and on the left five-eighths of an inch from the humeral end. Posteriorly there was no furrow or projection, but a slight deviation from the normal line beginning about an inch from the humeral extremity. On section, the cancellated structure above the line of fracture "was slightly condensed, but all remains of the callus seem to have been removed."

It is to be noticed that in three of these the fracture was oblique, and this corresponds with the result of experiments made by Sir Astley Cooper. He found that transverse fractures of the olecranon in dogs and rabbits united by fibrous tissues, but that union after very oblique fracture was bony, and he explained the difference in the result by the lack of contact between the fragments in the former case.

The length of the fibrous band varies within very wide limits. Figure 232 taken from Malgaigne represents a comparatively short band and

Fig. 232.



Fracture of the olecranon; fibrous union. (Malgaigne.)

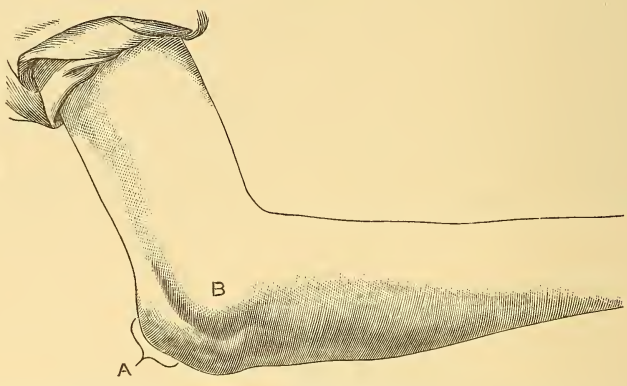
one that presents another peculiarity in that it consists of two lateral bands with a central interval or gap. This is by far the most common mode of reunion, and although several cases have been reported in which the patient appeared to have regained full use of the arm, notwithstand-

[1] Med. Times and Gazette, 1851, vol. ii. p. 173.

ing fibrous union with separation to the extent of half an inch or more, yet actual deficiency in the power of active extension of the forearm is to be regarded as the natural and almost inevitable result of fibrous union, and its degree will vary directly with the length of the band. The disability may be unnoticed by others, and its consequences may be avoided or diminished by care in the use of the arm, by avoidance of positions and movements which require the especial action of the triceps, but it exists and can be readily demonstrated. Malgaigne describes a case in which the fragment apparently had not reunited with the shaft, and yet the patient could use the limb actively, and even handle a sword or foil. On examination it was found, however, that the vigor and strength of the arm depended largely upon its position, being greatest when the hand was supinated and the arm dependent, and disappearing almost entirely when the arm was raised above the horizontal line.

Failure of union, as in the case just mentioned, is not very uncommon; the upper fragment may remain freely movable, or it may become adherent to the humerus. An example of the latter condition came under my observation in Bellevue Hospital. The patient, John A., 56 years old, was admitted in August, 1880, for some slight affection, and while examining him I noticed the defect of the right elbow. He said that when about twenty years old he fell from a truck, striking upon the elbow.

Fig. 233.



Ununited fracture of the olecranon. A, the upper fragment. B, the external condyle. (From a photograph.)

The limb was treated in a rectangular splint. The upper fragment, as shown in figures 233 and 234 taken from photographs, is slightly drawn up and somewhat tilted, and is firmly adherent to the humerus. The forearm can be completely flexed and can be extended to 135°, the force of extension being very feeble.

A similar case was presented to the Pathological Society, of London, by Wm. Hutchinson.[1] The patient had received a transverse fracture of the olecranon ten years previously which was treated with the elbow flexed.

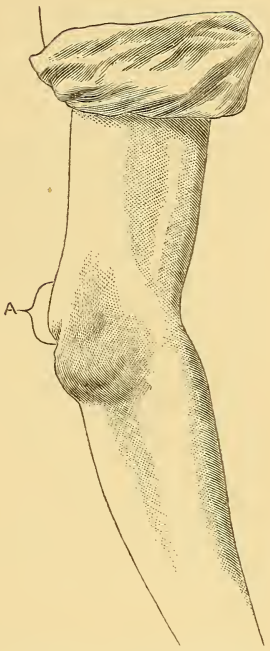
[1] Lancet, 1881, vol. i. p. 56.

"The fragment is fixed almost immovably to the humerus with a wide gap between it and the ulna, in which there appears to be not any uniting medium. He has power in his triceps and can partly extend the elbow; he has also partial paralysis of the ulnar nerve, with contraction of the ring and little fingers, numbness, and wasting of the muscles between the thumb and forefinger."

In the majority of cases union takes place with but little separation and with full restoration of function, so far at least as power is concerned, although extension is often incomplete.

A still more unfortunate result, ankylosis of the joint, has followed in a small number of cases. Malgaigne quotes from Camper and Trioen, an anatomical specimen of bony fusion, and although it is not specifically asserted that the union was between the ulna and the humerus, this seems probable from the context. Thierry, according to Pingaud, reported two cases of articular rigidity that had lasted, the one for six months, the other for a year, in spite of the most persistent efforts to overcome it.

Fig. 234.



The same; the arm extended.

The course of the fracture is ordinarily very simple and uncomplicated; the swelling subsides promptly and union takes place in from three to four weeks.

Treatment.—Discussion concerning the proper treatment of fracture of the olecranon has turned mainly upon the position to be given to the limb, some favoring the extended position in order to secure closer union of the ligaments, others recommending flexion either because they did not fear separation of the fragments and sought the position that could be kept with the least discomfort, or because they feared ankylosis and wished to have the limb in the most favorable position if it should occur. It is evident from the facts that have been already stated that neither the first nor the third reason is sufficient to establish a rule of practice to be followed in all cases. The probability of the occurrence of ankylosis after simple fracture is very small, so small that it ought not to be weighed against that of non-union when the fragments are separated rather widely. On the other hand, the separation at first is so slight in many cases and the extended position so unnecessary to overcome it that if partial flexion is more comfortable to the patient, if it makes the restraint less irksome, it should not be denied him. Furthermore, there appears to be danger of two displacements in complete extension: if the fracture is at or near the base of the process the ulna can be readily dislocated forward; and secondly, effusion into the joint or swelling of the capsule may prevent the tip of the olecranon from sinking into the olecranon fossa to the usual depth, and under such circumstances com-

plete extension of the forearm would cause a tilting, an angular displacement of this fragment. This latter point has been made by several writers upon theoretical grounds alone, and although it seems reasonable and plausible, no confirmatory observation has been made, so far as I know.

The aim of treatment should be to secure bony union if possible, and, failing that, close fibrous union, and this consideration will regulate the position to be given to the arm. If there is wide separation which increases as the elbow is flexed, if the fragments cannot be brought well together except by extending the forearm, that position must be taken and kept until consolidation is well advanced. If, on the other hand, the separation is slight and the upper fragment follows the movements of the lower, if they can be easily brought together and kept so by moderate traction upon the upper one, the patient may be safely allowed the comfort of the partly flexed position.

Apparently it is not often necessary to take especial measures to draw the upper fragment down to the lower one, and even when there is considerable separation between them in the flexed position it is usually sufficient simply to extend the elbow. Some methods of treatment, however, have been designed with the especial intention of drawing the fragment down, and it has been sought to accomplish this by figure-of-8 bandages passing above and below the fragment and crossing in front of the elbow, or by circular bands about the arm drawn together by longitudinal ones. In others, strips of adhesive plaster have been applied to the skin above the olecranon, drawn down snugly, and fastened to the skin of the forearm or to the splints ; sometimes the plaster is cut in the form of a U, the olecranon lying in the angle and the two sides passing along the forearm.

Metal hooks similar to those used in fracture of the patella have also been used here successfully, although not frequently. I do not know when or by whom they were first employed, but Busch recommended them in 1864, and Pingaud[1] speaks of the use of a similar method "a very long time ago" by Prof. Rigaud, of Strasburg. It is sufficient that the hook should have but a single point at the upper end, and that the other end should be made fast to a gypsum bandage covering the arm and forearm, and provided with a large fenestra behind the elbow.

The best splint is an anterior one made fast to the limb by a roller bandage or a fenestrated gypsum bandage. It is not worth while, I think, to try to force the upper fragment down by turns of a roller bandage, because this can be done much more effectively when necessary by adhesive plaster or hooks. In short, the treatment to be recommended is as follows : If the separation is slight and is not increased by the flexed position it is only necessary to immobilize the limb with the forearm slightly flexed, about midway between complete extension and flexion at a right angle, and for this purpose an anterior splint of wood or of plaster of Paris is sufficient and convenient. If the fragment shows any tendency to be drawn up it should be secured with adhesive plaster. If, on the other hand, there is notable separation, and if the

[1] Dict. Encyclopédique, art. Coude, p. 639 (1878).

separation is increased by flexion of the forearm, the extension should be complete enough to bring the fragments together, and it should be aided by adhesive plaster or hooks. The fenestrated gypsum bandage seems to be the one best fitted for this purpose, and the fenestra should be large enough and so placed as to permit inspection of the seat of fracture. If Malgaigne's hooks are used in connection with it one hook or pair of hooks should be forced through the tendon of the triceps down to the bone, and the other pair fixed to the gypsum bandage below the fenestra. In one of three cases recorded by Quintin,[1] the hooks remained in place four weeks without causing any inflammatory symptoms.

If the patient is rheumatic, or if the reaction has been severe and prolonged, and ankylosis is feared, it is well to change the degree of flexion slightly from time to time after the pain and inflammation have disappeared; and if the tendency to separation is slight this change of position may be begun quite early. It must be done very gently and cautiously, and the upper fragment must be supported by the finger in order that the adhesions may not be ruptured. In a case reported by Pingaud,[2] the callus was broken by this attempt at passive motion; and as the surgeon did not dare to immobilize the joint again for three or four weeks he applied a plaster bandage to the forearm, and used it as the support for a pair of Malgaigne's hooks by which he was enabled to keep the fragment perfectly in place, and at the same time to move the elbow as much as he wished.

Lauenstein[3] has used in one case a method of preliminary treatment recommended by Volkmann in fracture of the patella; aspiration of the joint to remove the blood and synovia. There was separation to the extent of half an inch and the joint was distended; he removed fifty cubic centimetres (about $1\frac{1}{2}$ ounces), dressed the limb in the extended position upon an anterior splint, and drew down the fragment by means of longitudinal strips of adhesive plaster renewed about once a week. Recovery followed without displacement and with full use of the joint.

In a few cases of fibrous union with much separation and consequent disability operative measures, according to some of the various plans mentioned in Chapter IX., have been undertaken to obtain closer union; and since the introduction of the antiseptic method some surgeons have obtained good results by excising the fibrous band and wiring the fragments together, as in the following case.[4] The fracture had united by a fibrous band with loss of the power of active extension. Three months after the injury, Mr. Rose cut down upon the fracture and wired the fragments together, passing the wires in such a way that they did not enter the joint. He used antiseptic precautions and horse-hair drains, began passive motion on the tenth day, and removed the wires after the end of the fifth week. The result was bony union of the fracture with good use of the joint.

2. Fracture of the Coronoid Process.—This fracture, the frequency of which has been much disputed, is unquestionably very rare

[1] Centralblatt für Chirurgie, 1881, p. 764.
[2] Gazette Hebdomadaire, May 21, 1875.
[3] Centralblatt für Chirurgie, 1881, p. 172.
[4] Lancet, 1880, vol. i. p. 835.

except as a complication of dislocation of the ulna backward. Dr. Hamilton devotes several pages to a discussion of the alleged cases of this injury and rejects most of them as unproven, saying in conclusion "we are left with no evidence that the coronoid process was ever broken by the action of a muscle, and with only one example in which it is probable that a fracture occurred as a consequence of a dislocation of the radius and ulna backward." To reach this conclusion Dr. Hamilton has had to reject all alleged cases supported only by clinical evidence and three of the four specimens of which he had knowledge. These four are the cases of Sir Astley Cooper, Samuel Cooper, Velpeau, and Dr. Gibson of Richmond, and he accepts only the first. He rejects the second because "it seems to have been a general crushing of all the bones concerned in the formation of the elbow-joint," the third, because he lacks a circumstantial knowledge of its condition, and the fourth, because "he finds it easier to believe that Dr. Gibson is deceived by certain appearances than that it [the fracture] should have united by bone again, and so perfectly as not to leave any line of separation or degree of displacement."

These arguments for rejection do not seem sufficient; and in view of the possible importance and frequency of the lesion I think it desirable to present the reasons for claiming that the occurrence of fracture of the coronoid process has been demonstrated by direct anatomical evidence, that the possibility of repair without notable displacement has been similarly proven, and that, as its occurrence as a complication of dislocation of the elbow backward has been demonstrated by direct examination and by experiment, the diagnosis in the numerous clinical cases in which its existence has been asserted must be accepted as in all probability correct.

The anatomical proofs are twelve in number.

1. The specimen mentioned by Sir Astley Cooper (loc. cit., p. 411). It was found in the dissecting room, was without history, and is preserved in the museum of St. Thomas's Hospital. "The coronoid process which had been broken off within the joint, had united by a ligament only, so as to move readily upon the ulna, and thus alter the sigmoid cavity of the ulna so much as to allow in extension that bone to glide backwards upon the condyles of the humerus." The external condyle was also broken off and united by ligament.

2. A specimen contained in the University College Museum and described by Samuel Cooper.[1] There is fracture of the ulna "at the elbow," fracture of the coronoid process, and dislocation of the head of the radius.

3. A specimen in the possession of Dr. Chas. Gibson, of Richmond, Va.[2] "The process was broken transversely near its extremity, and has united again quite closely and without any displacement, and without ensheathing callus."

4 and 5. Two cases observed by Velpeau.[3] He says in a note attached to a paper by Debruyn upon dislocations of the elbow, "when

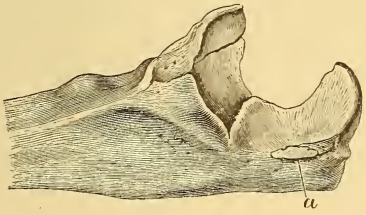
[1] Quoted by Hamilton, loc. cit., p. 342.
[2] Hamilton, p. 343.
[3] Annales de la Chirurgie, vol. ix., 1843, p. 98.

the forearm is dislocated backward it happens, more frequently than seems to be thought, that the coronoid process is broken. I have seen this fracture, which was first mentioned by Bérard, in two patients whose elbows I was able to dissect after their death." The details of one of these cases are given in the same publication, vol. i. p. 299. The patient was a man 50 years old whose elbow was dislocated in a fall. Six weeks afterwards he consulted Velpeau who recognized a dislocation but was unable to reduce it. The patient died of erysipelas and the autopsy showed fracture of the coronoid process, and a transverse fracture of the anterior third of the head of the radius.

6. Bérard[1] in 1834 examined the body of a man who had been killed by a fall from the second floor of a building. The elbow showed the signs of a dislocation backward which could be reduced without much difficulty and reproduced with slight crepitation by moderate pressure. The dissection showed a fracture of the coronoid process, and fracture of the head of the radius separating a fragment composed of the anterior third of the articular surface and the adjoining half inch of the anterior aspect of the neck.

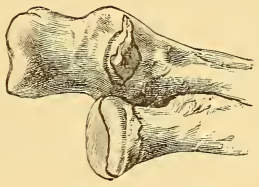
7. A specimen (fig. 235) preserved in the museum at Braunschweig, and described and pictured by Gurlt (loc. cit., vol. i. p. 41, fig. 10). Fracture of the extremity of the coronoid process of the right ulna; the line of fracture is visible about two and a half lines from the point on the articular surface. On the ulnar border of the articular surface of the olecranon is a small fragment which has been broken off and has reunited.

Fig. 235.



Fracture of coronoid process of the right ulna. United with exuberant callus on the anterior surface, line of fracture still visible on the articular surface. *a*, a small fragment broken from the articular border of the olecranon and reunited. (Gurlt.)

Fig. 236.



Fracture of the coronoid process and the head of the radius. (Bryant.)

8. A specimen in the museum of Guy's Hospital (fig. 236) described and pictured by Bryant.[2] The patient was a woman 70 years old, and the injury was caused by a fall upon the elbow. The anterior third of the head of the radius was also broken off.

9 and 10.[3] Specimens preserved in St. George's Hospital and taken from the body of a man who was killed by falling from the roof of the hospital. Both forearms were dislocated backward, both coronoid processes broken, and the head of each radius split longitudinally.

[1] Dict. de Médecine en 30 volumes, art. Coude, p. 228.
[2] Surgery, 3d Am. ed., p. 837.
[3] Holmes's System of Surg., Am. ed., vol. i. pp. 859 and 860.

11. Allandale[1] describes in a clinical lecture an excision of the elbow for an old unreduced dislocation of the forearm backward in a girl 18 years old. After having removed the olecranon he says "we now find that there has been a fracture of the coronoid process at the time of the accident which has been followed by a deposit of callus and some consequent osseous adhesion of the humerus to the ulna."

12. The first case quoted on page 432 from Dr. Hodges's second paper, one of multiple fractures at the elbow, fractures of the head of the radius, the olecranon, and the coronoid process.

As regards experiment upon the cadaver we have the assertion of Malgaigne (*Luxations*, p. 634), that in producing dislocations backward he broke off the end of the coronoid process quite frequently, and the more detailed results of Lotzbeck[2] who fixed the elbow in a slightly flexed position by means of a gypsum bandage and then by striking upon the palm of the hand broke the coronoid process five times in ten attempts. Varying the experiment by extending the elbow completely he succeeded in producing the fracture only once.

The mechanism of this production and the anatomical relations of the process explain the union with slight displacement shown in some of the specimens and the difficulty of diagnosis during life. The tendon of the brachialis anticus is inserted not upon the tip of the process but upon its anterior aspect and base, and the articular capsule is attached all along its edge. When it is broken off by being forced backward against the trochlea its connection with the ulna is preserved in front by the tough attachments of the tendon, and therefore instead of being displaced bodily along the anterior aspect of the bone it is probably only tilted forward. Its vitality is assured in any case by its connection with the capsule, and when the dislocation is reduced the fragment is held exactly in place by the tendon of the brachialis anticus in front and the humerus behind.

The clinical symptoms upon which the diagnosis has been usually made are a dislocation of the elbow backward, its easy reduction and easy reproduction, crepitation, and sometimes the presence of a small, hard movable body in the fold of the elbow in the line of the tendon of the brachialis anticus.

So far as can be inferred from the few detailed descriptions of specimens the line of fracture crosses the process transversely or somewhat obliquely at about one-fourth of an inch below its apex, and may reunite with a close bony union as in Cases 3, 7, and probably 11, or by a fibrous band as in Case 1. When the union is close and bony there may be a somewhat exuberant callus upon the anterior aspect of the process, due probably to the stripping up of the periosteum or tendon.

The mechanism in the great majority of cases is by indirect violence exerted in such a way as to cause dislocation of the joint backward and to break off the point of the process as it is forced past the trochlea. In one case mentioned by Lotzbeck the process appeared to have been broken off by direct violence; a soldier was struck in the elbow by a

[1] Med. Times and Gazette, 1875, i. p. 576.
[2] Schmidt's Jahrbuch, vol. 129, 1866, p. 134.

piece of a shell which caused a severe contusion but no open wound. Two months afterwards the coronoid process could be felt as a movable body, and by pressing it down it could be made to rub against the ulna with a creaking sound. Acupuncture proved the supposed fragment to be a hard solid body.

In another case, that of a boy 14 years old, the process was broken off by extreme flexion of the elbow. A somewhat similar personal experience may be mentioned as corroborative of this mechanism to a certain extent. I excised an elbow for suppurative disease of the joint, using Ollier's postero-lateral incision. In order to facilitate the cleaning of the external condyle, and before the olecranon had been touched, I asked the assistant to flex the elbow; he did so with some force, and felt something snap. On examination, about half an inch of the coronoid process was found to have been broken off. It seemed to me, however, to be unusually long and prominent, possibly by ossification of the attached capsule in consequence of the prolonged inflammation.

The symptoms and the means of diagnosis, in view of the uncertainty of the diagnosis in the supposed cases, cannot be positively described; those which have been considered sufficient have been mentioned above: dislocation backward, easy reduction, great tendency to recurrence, possibly crepitation, and the presence of a hard movable body in front of the elbow in the line of the tendon of the brachialis anticus. In the only case that has come under my observation, a case which I was invited to see by my friend and colleague, Dr. Keyes, the supposed fragment could be readily grasped between the thumb and finger and moved freely to and fro.

The *treatment* consists in immobilization of the joint flexed to a right angle or beyond. The degree of flexion and the completeness of the immobilization may vary with the tendency to displacement. If the latter is great, experience has shown that it is best opposed by increasing the flexion, and of course complete immobilization gives additional security. A posterior or lateral splint or a plaster moulded one may be used. Velpeau recommended that the immobilization should be maintained for at least four weeks and the opinion has been shared by many distinguished surgeons, but I think the practice Dr. Hamilton recommends is likely to be sufficient in most cases; he advises the use of the splint for a week or ten days and then a simple sling. The guide in this matter will be the tendency to displacement; when that ceases the splint becomes unnecessary, and the only indication is to maintain sufficient flexion to favor prompt and close union. The slight motion in the joint permitted by a sling, if it is painless, diminishes the resulting stiffness.

3. Fractures of the Head and Neck of the Radius.—Our knowledge of this variety of fracture is drawn from about a dozen specimens and two or three doubtful cases. Partial fracture of the head of the radius in connection with fracture of the coronoid process of the ulna (fig. 236) is the form that has been most frequently observed. Five of the cases have been given in the preceding section (Cases 5, 6, 8, 9, and 10, page 429), and in all the position and extent of the fracture seem to have been the same, crossing the articular surface transversely and extending about half an inch down the neck, thus breaking off a fragment

which comprises the anterior third or fourth of the articular surface. Dr. Hamilton saw "in Dr. Mütter's cabinet two specimens of fracture of the outer half of the head of the radius. In one case the small fragment is slightly displaced downwards in the direction of the axis of the bone; and in the other the fragment is thrown outwards, or to the radial side. Both are firmly united in their new positions."

Dr. Hodges[1] presented to the Boston Society for Medical Improvement, Oct. 8, 1866, a specimen of fracture of the head of the radius taken from the body of a man who died a few hours after having fallen from a height of sixty feet. Although there was but little swelling, and the conditions were exceptionally favorable for the examination, the fracture was not recognized during life. The autopsy revealed a "longitudinal fracture of the head of the radius. The specimen presented a clear and regular split involving very nearly one-half the head of the radius, cleaving outwards so as to extend no further than the neck of the bone. It was accompanied by a very oblique fracture of the shaft of the ulna, commencing at the depression of the articular surface marking the separation of the coronoid process and the olecranon, extending almost longitudinally three and a quarter inches downwards, and detaching from the shaft that portion of the bone to which the olecranon was attached." Dr. Hodges refers to reported cases of similar fracture of the radius associated with fracture of the coronoid process, and points out their close resemblance to this one, since a slight deviation of the line of fracture would have separated the coronoid process at its base.

In a subsequent paper he reports[2] five additional cases: (1) A man, forty years old, fell from a height of forty feet and received a compound fracture of the elbow. The head of the radius was split into two unequal parts, neither of which was completely detached; the olecranon and coronoid process were broken from the ulna. (2) A man, twenty-four years old, fell against some machinery in motion and received a compound fracture of the elbow, the external condyle of the humerus and one-third of the head of the radius being broken off. (3) A specimen in the Warren Museum without history, No. 1023. Fracture of the shaft of the radius. "Upon the head of the bone is a small fragment $\frac{3}{8}$ inch in diameter, chipped, as it were, from the articulating surface. The fragment has a well defined outline, and is united in place without any signs of new growth of bone around it." (4) A man, fifty-five years old, received a compound comminuted fracture of the elbow by the fall of a mass of stone upon it. Excision. The head, neck, and shaft of the radius were split for $1\frac{1}{2}$ inches into three pieces, and the external condyle of the humerus broken off. (5) A gunshot fracture similar to the last.

Dr. Hamilton quotes the description furnished him by Dr. Mütter of a specimen of fracture of the "neck of the left radius just at the upper extremity of the bicipital protuberance" in the latter's cabinet, and adds a drawing of the same (fig. 237). The fracture has united with deformity, the articulating surface facing backward and its anterior edge lying in contact with the humerus.

[1] Boston Med. and Surg. Journal, 1866, vol. lxxv. p. 383.
[2] Boston Med. and Surg. Journal, 1877, vol. xcvi. p. 65.

In a case that came under my own care the outer half of the head of the radius was broken by direct violence. The patient, a boy thirteen years old, was admitted to the Presbyterian Hospital, March, 1877, with suppurative arthritis of the right elbow following a blow received two months before; a playmate had thrust at him with a sled, and the sharp end of the iron-shod runner had struck him upon the outer side of the elbow. I excised the joint, and in the course of the operation found the outer half of the head of the radius separated from the rest and from the shaft, with an irregular surface of fracture and preservation of the articular cartilage. There was about half an ounce of thick brownish pus in the cavity of the joint, and the articular cartilage of the ulna was eroded and hanging in shreds.

Fig. 237.

Fracture of the neck of the radius; union with displacement. *a*, articular surface. (Hamilton.)

The symptoms were complete muscular fixation of the joint at a right angle, swelling of the posterior and lateral regions of the joint, tenderness on pressure over the head of the radius and on movement; rotation of forearm painful and very limited; the skin was normal, except for some reddening over the head of the radius.

In another case the head of the radius was broken in a dislocation of both bones backward. The patient, a man twenty-seven years old, was admitted to the Presbyterian Hospital, April, 1882, with a backward dislocation of the right elbow, produced by a fall from a wagon upon the palm of the hand. I reduced the dislocation under ether, and then felt a movable piece of bone on the outer side between the olecranon and the head of the radius. As the olecranon, external condyle, and accessible portion of the radius appeared uninjured, I thought it must be a fragment from the inner side of the head of the radius and removed it with antiseptic precautions. It was part of the head of the radius, about one-third.

Dr. W. R. Townsend treated a case of supposed fracture of the head and neck of the radius in Bellevue Hospital in 1881. The patient was a stout, muscular man, thirty-nine years old, who fell from a ladder, striking upon the outer side of his left arm, which was held close to his body. After the swelling had subsided a movable piece of bone could be felt at the side of the head of the radius; crepitus could be felt when the wrist was rotated. The diagnosis was confirmed by Drs. McBurney and Yale. I saw him a year later, in April, 1882; flexion of the left elbow was complete; extension incomplete, to about 140°; pronation and supination limited to about 90°; some pain in damp weather. The head of the radius is very irregular, its diameter greater than usual, and the distance from its upper edge to the top of the olecranon nearly

an inch greater than on the right side. The prominent upper part of the head of the radius moves nearly an inch on rotation of the wrist. The edge of the outer condyle of the humerus feels a little irregular. The arm was strong and useful, and the patient had returned to duty in the fire department as steersman of a hook and ladder truck.

In the few supposed cases that have been reported the diagnosis has either been overthrown by the autopsy, or is so uncertain that but little value can be attached to the symptoms upon which it was based. In three supposed cases seen by Dr. Hamilton at periods varying from ten weeks to fifteen months after the accident, a bony projection could be felt in front of the elbow at a point corresponding to the radius, and there was almost complete loss of motion. On theoretical grounds I should hope to obtain crepitation in a case of partial fracture of the head by making pressure upon it with the finger, and rotating the wrist gently. The same exploration might yield the same result after complete fracture of the neck, or even demonstrate the independent mobility of the shaft.

Moore[1] reported a case of "fracture of the neck of the radius," observed by himself three years after the receipt of the injury, but the fracture was evidently below the insertion of the biceps. Some of the details may be found in the section on Fractures of the Shaft of the Radius (page 444).

While the cases are too few in number to establish the prognosis definitely, they show two possible results: union, and chronic inflammation of the joint. Mütter's three specimens show that repair is possible; the means by which it is produced may be doubtful, but probably the periosteum of the neck remains untorn and keeps up vascular communication between the shaft and the fragment. Moreover, as has been stated elsewhere, even if the fragment should be entirely severed, it is not impossible for new communications to be established and bony union to follow. In my first case disorganization of the joint, suppurative arthritis, followed and rendered excision necessary; this patient was a delicate, strumous lad. In only one of the remaining cases not operated upon, Velpeau's, did the patient survive the injury for more than a few hours, and in the report of this no mention is made of the existence or absence of repair. After complete fracture of the neck above the bicipital tuberosity the biceps might be expected to draw the upper end of the shaft forward, and this is the explanation which Dr. Hamilton suggests of the deformity in the three cases observed by him. In Mütter's specimen of fracture of the neck repair appears to have taken place with marked angular displacement in this direction.

Treatment after partial fracture of the head will be regulated by the fracture of the coronoid process or ulna with which it has been associated in all the recorded cases; if the fracture of the radius should be recognized, or even strongly suspected, I should make immobilization more complete, and maintain it for a longer time than in simple fracture of the coronoid process, because the vitality of the fragment can be preserved or regained only by the spread into it of granulations coming

[1] London Med. Gazette, 1845, vol. xxxvi. p. 1079.

from the main portion, and the more perfect the quiet, the more probable would be the accomplishment of this desired result.

After complete fracture of the neck the elbow should be immobilized at a right angle for at least four weeks, and forcible passive motion should not be made until after consolidation is thought to be complete.

B. Fractures of the Shaft.

1. Fractures of the Shafts of both Bones.—The relative frequency of fracture of both bones may be seen by reference to the table given in Chapter XIX. It occurs rarely in the upper third; according to Hamilton only 6 times in a total of 73, 31 being in the middle third, and 35 in the lower third. Usually the radius is broken nearer the elbow than the ulna.

Direct violence is a frequent, according to some the most frequent, cause of the fracture, the limb being broken by a blow, by the passage of a wheel, or by a fall against some object. Fractures by indirect violence are caused by falls upon the hand, and while fractures of the radius alone are the more common result of this accident, yet both bones may be broken, and in some cases it seems clear that the fracture of the ulna follows, and is in a measure the consequence of that of the radius.

Only a few instances of fracture by muscular action have been recorded. Malgaigne reports a case in which a healthy robust lunatic 38 years old, broke both bones while shovelling. As he sought to raise the shovel with its charge of earth, he heard two distinct snaps in his right forearm, and was unable to continue his work. The next day Malgaigne found a fracture of the radius near its centre and one of the ulna about an inch nearer the wrist, with considerable displacement. Velpeau[1] reports a similar case, the patient being a large strong man, and Gurlt[2] one communicated to him by Ulrich of a healthy woman, 37 years old, who broke both bones of the forearm and the fifth metacarpal bone by rising in bed and supporting herself upon the hand on the third day after her fifth normal confinement.

Partial or incomplete fractures, "green-stick fractures," are, according to Malgaigne, more common in the forearm than elsewhere, and are usually due to a fall upon the hand. My personal experience is limited to a very few cases, and although I have not been able to obtain very definite descriptions of the accidents from the youthful patients or their attendants, it has seemed probable that the fractures were caused rather by the arm being caught and twisted under the body than by direct impact upon the hand. In one case the patient, a large muscular lad 18 years old, was caught in machinery and had his left arm twisted about a reel or shaft. There was marked angular displacement at the junction of the lower and middle thirds of the forearm, the lower segment being inclined sharply forward. Rotation diminished; pain on pressure at the angle. By placing my knee against the projecting part and drawing

[1] Gazette des Hôpitaux, 1850, p. 76. Quoted by Gurlt.
[2] Loc. cit., vol. i. p. 244.

back forcibly upon the wrist and elbow I was able to reduce the displacement almost entirely. There was no crepitus, and no mobility. The humerus was broken at its middle.

The line of fracture is either smoothly oblique or transverse with large serrations, and in other respects may show the varieties observed in the fractures of other long bones, such as splintering, comminution, and multiplicity of fracture. In a specimen preserved in the Museum of Bellevue Hospital there are two fractures of each bone; one pair, complete, in the middle third, the other pair, incomplete, infractions, close by the wrist. There was also a fracture of the humerus; the limb was removed by amputation.

The displacements are of the usual kinds: overriding in oblique fractures, lateral with or without overriding in the transverse fractures, and angular displacement of one or both bones in both forms. Rotatory displacement of the radius alone, especially when it is broken above the insertion of the pronator teres, was first pointed out apparently by Lonsdale. He suggested that the upper fragment might be strongly supinated by the biceps, while the lower fragment was kept in the usual semi-prone position, and he thought this might be a cause of the inability to supinate the hand completely, sometimes observed after fracture. Flower and Hulke[1] say they have found proof of the correctness of this conjecture in the examination of numerous specimens of united fracture of the radius, "in a great number of which the lower fragment was much less supinated than the upper," and Agnew says there are similar specimens in the collections of the College of Physicians and the University of Pennsylvania. Mr. Callender[2] examined 18 specimens of united fracture of the shaft of the radius in the London Museum, and found in 15 of them rotatory displacement averaging 36°, the extremes being 6° and 64°. The displacement in every case was that pointed out by Lonsdale, supination of the upper fragment.

In angular displacement one bone may be sharply bent in towards the other, which remains nearly straight, or the fragments of both bones may be inclined in the same direction, forward, backward, or to either side, or there may be lateral inclination in opposite directions, each bone being inclined towards the other; and if the fractures are on the same level the four ends may thus be brought into contact, and the possibility created of a union that will abolish the power of rotation of the limb. In the case quoted above from Malgaigne, the lunatic who broke his arm while shovelling, the ends of the upper fragments were brought together and interposed between the ends of the lower fragments, and in addition there was a displacement produced by supination of the lower segment of the limb, one which brought the lower fragment of the radius behind the upper one, and that of the ulna in front of its upper one. A displacement, the direct opposite of the latter, has also been observed and described by Malgaigne, the lower segment of the limb being more pronated than the upper one. Overriding of the fragments has been observed to a distance of more than three inches (eight centimetres).

[1] Holmes's System of Surgery, Am. ed., vol. i. p. 860.
[2] St. Bartholomew's Hospital Reports, vol. i. 1865, p. 297.

The *symptoms* are the usual ones of fracture; pain, deformity, abnormal mobility, crepitation, and loss of power.

The *course* is usually simple and the *prognosis* favorable, but both may be gravely modified by laceration or bruising of the soft parts or by the occurrence of acute inflammatory reaction or of gangrene, and in addition the prognosis may be made unfavorable by an irreducible displacement or comminution or loss of substance of one of the bones. Displacement affects the prognosis when it increases the chances that union may take place between the two bones, and comminution or loss of substance by favoring the occurrence of pseudarthrosis.

In simple cases without marked displacement or complication complete union may be expected in a month, but in no other limb do inflammatory complications and gangrene occur so frequently, even under prudent treatment. The gangrene may be limited to points where the splints have made pressure or to portions of the hand and fingers, but it is very likely to involve the entire member if it is overlooked at the beginning or not effectively combated. Diffuse phlegmonous inflammation of the forearm may follow severe bruising of the soft parts or may even take its rise in the fracture. Its importance lies in the danger to the life and limb which follows the burrowing of the pus, the openings which it necessitates, and the matting together of the tendons and their sheaths. Demarquay says he has often seen muscular atrophy follow fracture of the forearm, the result of this inflammatory process, and while writing this section I was consulted in a case of such atrophy and limitation of the movements of the fingers due to inflammation following a simple fracture of both bones by direct violence.

The cause of the gangrene in many cases has been pressure exerted by splints or bandages, and the necessity for caution and watchfulness to avoid this accident cannot be urged too strongly. The practice of applying a roller bandage to the limb under the splints is extremely dangerous, and so also is the use of splints of soft material, pasteboard and the like, which take the shape of the limb and are fastened to it with a roller bandage. There is the same compression, the same chance of strangulation in this case as when the roller is applied directly to the skin. It is not safe to depend upon the sensations of the patient, upon pain, to give warning of threatening strangulation; cases, in both old and young, have been reported in which total gangrene of the distal portion of the limb has occurred without attracting the attention of the patient or his attendants by any symptoms except the final change in the color of the exposed fingers. Dr. Hamilton gives a number of illustrative examples, of which I reproduce the following; in two of them the gangrene may be fairly attributed to the dressing, and in the third probably to the bruising of the soft parts by the original violence supplemented by the pressure of the splints which became excessive when the limb swelled.

1. A child 2¼ years old fell from a chair to the floor, breaking both bones of the left forearm near the middle. A physician applied a roller bandage from the fingers to the elbow, and over this three light narrow wooden splints, one in front, one behind, and one on the radial side, and bound the whole together by another roller. The child continued to

play about, and ten days afterwards the doctor noticed that the ulnar side of the little finger was blue. The bandages were immediately removed and never again applied tightly.

Three or four days later the gangrene had extended over the whole of the little finger and most of the thumb, and there were gangrenous spots over the hand and forearm extending to within one inch from the elbow-joint; these spots seemed to correspond to the pressure of the splints. The hand was much swollen, and also the arm above the line of the gangrene. The sloughs had already begun to separate, and the gangrene was extending at only a few points. The child appeared well. The arm and a large portion of the hand were saved.

2. A young man, 20 years old, suffered a simple fracture of the right radius and ulna, which was dressed on the same day with a roller next to the skin and over this the splints. On the next day the fingers were black, but the dressings were not removed until the third day when he was admitted to Bellevue Hospital. There had been no pain after the first few hours. Three weeks afterwards he was seen by Dr. Hamilton and had then lost all the fingers and part of the thumb, and there were extensive suppuration and sloughing along the forearm. He died a few days afterwards.

3. A young man, 22 years old, was admitted to Bellevue Hospital with a fracture of the left forearm near its middle, caused by the kick of a horse on the preceding day. The fracture was dressed with properly padded palmar and dorsal splints secured with a roller which included the hand and forearm, and the arm placed in a sling. On the third day he was walking in the yard when the surgeon's visit was made and was not seen by him. On the fourth day "he was apparently in perfect health, but as I stopped him a moment to look at his arm, I saw that the hand was swollen and purple. The dressings were immediately removed and the patient placed in bed. There were upon the arm two spots looking like superficial sloughs. He was suffering no pain. The gangrene subsequently extended until it involved a large portion of the hand and forearm, and on the eighteenth day after the receipt of the injury he died."

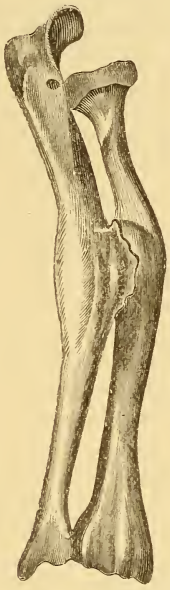
The possibility of union between the bones as well as the fragments should always be borne in mind. Its occurrence is more likely when the natural interval between them is destroyed or diminished by displacement, but this approximation is not essential. Excessive formation of callus, in consequence of laceration of the intermediate tissues and irritation especially of the interosseous membrane, is sufficient in itself to produce this result so destructive of the usefulness of the limb. The occurrence is favored also by correspondence in the position of the fractures, for the fragments are more likely to fall into abnormal contact with each other, and the granulations which form the callus about each fracture may easily unite if each spreads over only half the intermediate space (fig. 238). It has occasionally happened that the two calluses have come into contact and formed a lateral joint (fig. 239) instead of uniting. Such a specimen is said by Callender to be in the Museum of King's College. In other cases, again, rotation is diminished or abolished by union of one or both fractures at an angle, as in either of these

figures. Slight inclination of the hand to one side or the other is a not infrequent result and may be due to the position of the sling in which the arm is supported; thus, if the weight of the arm is borne upon the sling at or above the point of fracture the unsupported hand drops down-

Fig. 238.

Fracture of the forearm, angular displacement, and union between the bones.

Fig. 239.



Fracture of the forearm, with formation of a lateral joint.

ward and the lower fragment deviates toward the ulnar side, as in the figures; while if the sling passes under the hand or wrist and leaves the forearm unsupported the latter sinks down between the wrist and elbow and the lower fragment deviates in the opposite direction toward the radial side.

Delay or failure of union of either or both bones is not uncommon, and cases are reported in which the union of one of the bones has been delayed four or five months, and has then taken place without operative aid. Failure of union entails a disability that is practically complete, and Agnew's tables do not indicate that the prospects of relieving it by operation are very great, since out of thirty-seven cases a cure was obtained in only nineteen. Malgaigne says that he had seen in two cases rotation destroyed apparently by union of the upper fragments of the two bones, and solidity of the limb lost by the failure of union between the upper and lower fragments.

Treatment.—Reduction must be effected, when necessary, by extension and counter-extension aided by cautious pressure upon the bones near the seat of fracture. The importance of reduction is exceptionally great, because of the special function of rotation of the forearm which may be so easily destroyed by displacement. Overriding is to be over-

come by extension; the forearm and fingers are flexed, counter-extension is made by an assistant who grasps the arm close above the elbow, and extension by the surgeon himself or another assistant grasping the hand. If there is angular displacement the extension should first be made in the direction of the lower fragment, and when this is thought to be sufficient, and while it is still maintained, the lower segment of the limb is brought into line with the upper one, the latter being steadied by the hand of the surgeon or pressure being made upon the projecting angle with the thumbs. This pressure may be safely made if the angle is directed forward or backward, but it must be used with great caution when the angle is lateral, for there is danger that it may force the bone upon which it is made too near its fellow, and that when the manœuvre is completed the position of the fragments may resemble that of the arms of an X, each pair being displaced angularly toward the other. To avoid this result, which if left uncorrected is full of danger to the future usefulness of the limb, the hand should be supinated while reduction is making, because in this position the interval between the bones at the centre of the limb is greatest and most accessible, and the surgeon should seek to force or keep the fragments apart by pressing his thumbs in between them in front and his fingers behind.

The position in which the forearm is usually kept during treatment is that which is midway between pronation and supination. It is the one which the limb naturally assumes when it is suspended beside the body with the elbow bent at a right angle and is the one which is borne with the least fatigue and discomfort. But while this position meets the indications sufficiently in the simple and, indeed, in most cases, it was long since recognized by some surgeons that the bones of the forearm are normally separated most widely from each other at the centre when the limb is supinated, and that consequently this position is the one in which the arm should be kept whenever there appears to be danger of the bones uniting with each other. According to Malgaigne, fractures of the forearm were treated in the supine position by the contemporaries of Hippocrates, but the practice was condemned by that writer; it was reinvented by Paré, and abandoned by him when he learned that Hippocrates had disapproved of it, a yielding to authority that seems to have been unusual with that vigorous-minded surgeon, and again reinvented by Malgaigne, who afterwards learned that Lonsdale had preceded him by a few years. Lonsdale[1] recommended the position for a reason mentioned above, the difference between the degree of supination of the upper fragment of the radius and that of its lower fragment; Malgaigne recommended it because of the greater distance between the centres of the bones when they are in this position. The objection to it is the greater constraint and inconvenience of the position, an objection which of course should not be allowed to weigh for a moment against a serious risk of faulty union, and which, if it becomes great, should be met by rest in bed with the arm abducted and the elbow flexed at a right angle; in full supination the hand then rests easily on its ulnar border with the thumb directed upward.

[1] London Med. Gazette, 1832, vol. ix. p. 910.

The accepted method of treatment is to fix the limb between two light wooden splints broad enough to overlap it slightly when applied to the palmar and dorsal surfaces. The palmar splint should extend from the fold of the elbow to the roots of the fingers, the dorsal one should be shorter and not reach beyond the wrist. Each splint should be padded with cotton, and patients usually find it agreeable to have the end corresponding to the palm of the hand very thickly padded, or a small roll of bandage fastened obliquely to it so that the fingers can close easily over it. Dr. Hamilton recommends that the padding at the palmar surface of the wrist and just above it should be intermitted or made very thin so as to avoid painful pressure upon the median nerve.

In simple cases uncomplicated by threatening displacement, the splints are applied to the semi-pronated limb and fastened by two strips of adhesive plaster wrapped about them, one near the elbow, the other at the wrist, the hand is made fast to the palmar splint by a few turns of a badage, and the limb is placed in a sling that supports both the elbow and hand.

In other cases where the fragment threatens to encroach upon the interosseous space the splints must be applied with the limb supinated, and it is proper to employ a device introduced by Jean Louis Petit to force or keep the bones apart, although there is reason to doubt if it is very efficient. He sought to keep the fragments apart by making pressure between them with graduated compresses placed longitudinally under the splints. Malgaigne has pointed out very clearly the difficulties in the way of making effective pressure by this means, and has shown that the pads, if used at all, should be very short, not more than an inch or two in length, and placed at the centre of the arm where the interval between the bones is greatest. Other surgeons, Dr. Hamilton among them, are satisfied with the pressure of the muscles pushed back by flat or padded splints. Nélaton used corks instead of pads. Dr. E. T. Caswell[1] says of these pads that "if useful they are intolerable; if tolerable they are useless." If the supine position of the forearm proves inconvenient and troublesome, that of semi-pronation may be safely substituted after repair has fairly begun, say at the end of a week or ten days.

In either case the limb should be frequently inspected, daily for the first few days, in order to guard against excessive pressure either by bandages too tightly applied at first, or made too tight by the swelling of the parts, and to detect and remedy any new displacement.

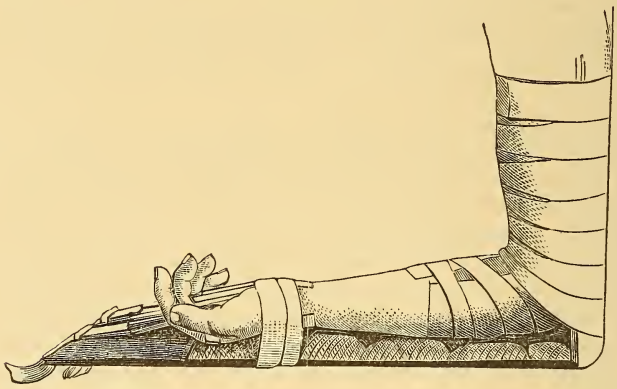
A roller bandage should not be applied to the limb under the splints; it can answer no good purpose, and it exposes to displacement by pressing the fragments toward each other, and to gangrene by constriction of the limb. The plaster-of-Paris dressing is equally objectionable for the same reasons during the first few days, and is to be avoided afterwards because it prevents inspection of the parts.

The anterior and posterior splints immobilize the limb sufficiently to meet every indication except that of opposing the tonicity of the muscles and the occurrence of overriding. When the lines of fracture are trans-

[1] Holmes's System of Surgery, Am. ed., vol. i. p. 861.

verse or toothed, the bones themselves afford sufficient protection, but when the fracture is oblique it is probable that repair will be accompanied by some shortening. This in itself would not have much importance, but if the transverse displacement which must accompany it is lateral, it may reduce the breadth of the interosseous space sufficiently to diminish rotation, or may even lead to lateral union of the bones. The lack of fixed points makes it difficult to oppose this tendency by means of the straight splints alone, and various plans have been suggested for making counter-extension upon the arm by means of an angular splint; the other fixed point is obtained by binding the hand and wrist to the other end of the splint. Figure 240 represents a splint used by Dr. X. C. Scott

Fig. 240.



Dr. Scott's splint for fracture of the forearm.

in a number of cases with good results; the extension is made by means of adhesive plaster secured to the hand and wrist.

In compound fractures great caution should be used in removing fragments or excising portions of bone, lest failure of union should follow. If the extent and position of the wound are such that efficient splints cannot be used at first, the patient should be kept in bed with the arm abducted and the elbow flexed, and extension, elastic or by weight, made by means of adhesive plaster attached to the hand and wrist. Counter-extension can be made from the lower part of the arm by a broad bandage, or from the upper part of the forearm by adhesive plaster, the limb being meanwhile supported upon cushions or suspended, and preferably steadied by a splint placed outside the dressings of the wound.

2. Fracture of the Shaft of the Ulna.—Fractures of the shaft of the ulna alone are almost invariably the result of direct violence, of a blow received upon the arm while it is raised to protect the head, or of a fall upon the ulnar side of the forearm. A case of fracture by muscular action is quoted in Chapter IV. p. 96.

Agnew states that of 88 cases treated in the Pennsylvania Hospital 27 were fractures of the upper third, 32 of the middle third, and 29 of the lower third. He mentions also the frequency, about 28 per cent.,

of comminution, simple or compound, and Dr. Hamilton says that in his experience serious complications are more frequently associated with fractures of this bone than with those of any other; of 36 cases observed by him 4 were compound, 12 complicated with dislocation of the head of the radius, and 1 each with dislocation of the elbow backward and dislocation of the lower end of the radius.

Displacement may be entirely absent, and when present may be in any direction. Its extent and direction seem to depend almost entirely upon the fracturing force. Most recent writers, following the example of Pouteau,[1] have alleged that the broad articulation of the ulna with the humerus prevented lateral displacement of the upper fragment, and that the lower fragment was therefore the only one that could be displaced towards the radius. Even if the articulation was absolutely free from lateral mobility, the inference that has been thus drawn would not be correct, because the radius can be moved towards the ulna after fracture of the latter and thus the exact equivalent of the displacement of the ulna towards the radius produced. The only muscle which acts directly upon the lower fragment is the pronator quadratus, the tendency of which is to draw it towards the radius.

The symptoms may be limited to pain and swelling at the seat of fracture, and their significance may be rendered obscure by the history and the effect upon the soft parts of the direct violence which has caused the fracture. If the radius remains entire and is not dislocated at either end, there can be no shortening of the limb, no overriding of the fragments, and displacement, if present, must be recognized by following the outline of the bone with the finger. Fortunately this exploration is made easy by the subcutaneous position of the ulna. Crepitus and abnormal mobility may be obtained by grasping the limb above and below the fracture and making pressure alternately upon the fragments with the fingers, or by seizing the fragments between the thumb and fingers and moving them forward and backward upon each other.

The prognosis is good as regards repair and preservation of function, although failure or delay of union is said by Dr. Agnew to be more common than in the radius, and displacement of the fragments towards the radius involves the possibility of loss of the power of rotation of the wrist. Dr. Hamilton mentions a fact which is of much prognostic importance unless his experience is entirely exceptional; he says (loc. cit., p. 334): "I have seen the radius left unreduced nine times after fracture of the ulna, and in each example the forearm was shortened." He refers to dislocation of the head of the radius forward.

Reduction can be made only by appropriate pressure upon the displaced fragments, extension being practically without value. The displacement which it is most important to overcome is the lateral one towards the radius, and that should be met in the same way as after fracture of both bones, that is, by pressing the thumb and fingers in between the bones.

As the radius acts as a splint to prevent overriding of the fragments the surgeon's chief care is to secure immobility and prevent lateral or

[1] Œuvres posthumes, 1783, vol. ii. p. 258.

angular displacement. This can be done by the anterior and posterior splints used in fracture of both bones, or by a rectangular splint fastened against the inner side of the arm and semi-pronated forearm, or by a moulded plaster splint. In some cases it may be necessary to keep the forearm supinated, and in others the bruising of the soft parts may be so severe as to forbid the use of splints at first and require rest with cooling applications for several days. The arm should be kept in a sling and the same precautions should be taken to avoid undue pressure by the sling upon the ulna as when both bones have been broken. Many surgeons place the limb in a pasteboard, felt, or plaster gutter in order to avoid this danger. In case of need an interosseous compress may be used under the anterior and posterior splints to keep the fragments away from the radius.

3. Fracture of the Shaft of the Radius.—As far as can be judged from general impressions and statistics that are somewhat scanty, isolated fracture of the shaft of the radius is even less frequent than that of the ulna, and appears also to be generally caused by direct violence, sometimes by a fall upon the hand, especially if at the same time dislocation of the lower end of the ulna takes place. An instance of fracture in the lower third by muscular action is quoted in Chapter IV. page 96.

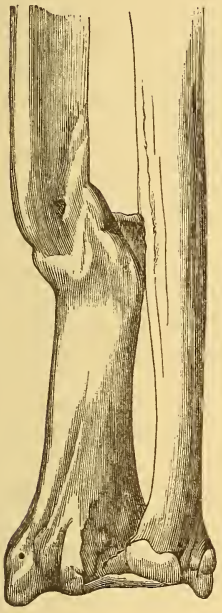
The displacements vary somewhat with the point at which the fracture takes place, the causes of the displacement being the fracturing cause, and the action of the biceps and pronator muscles. In a case reported by J. Moore[1] as "fracture of the neck of the radius" but of which he says "the fracture appeared to have commenced just inferiorly to the insertion of the biceps tendon, and to have extended upwards and backwards through its neck," the upper fragment, which was one and a quarter inches long, was drawn upward by the biceps and the lower fragment had united with it at almost a right angle. The patient was a girl 24 years old, and the fracture was caused by a fall from a stool, a compound fracture of the ulna in its lower third was produced at the same time and the fracture of the radius was overlooked. Doubtless the fracture of the ulna united with shortening and thus made union of the radius with angular displacement possible. The case properly belongs among fractures of both bones, and is mentioned here only as a demonstration of the action of the biceps.

The fragments may be displaced in any direction, but the more common displacement appears to be an angular one, the apex of the angle being directed forward and towards the ulna. Figure 241 shows displacement of the upper end of the lower fragment alone towards the ulna, the fragments turn upon the lower radio-ulnar joint as a hinge with the effect of raising the styloid process of the radius to the level of that of the ulna, and of changing the direction of the lower articular surface of the radius so that the hand is inclined toward the radial side. This displacement is much more marked in figure 242, since there the fracture is at a lower point, only two inches above the end of the bone. In this case it is true that both bones have been broken, but as the ulna has

[1] London Med. Gazette, vol. xxxvi. 1845, p. 1079.

united without displacement its fracture has had no share in producing displacement of the radius. The higher the fracture the less is the change in the direction of the lower articular surface, but the possibility of the loss of the power of rotation of the wrist is the same since it depends on the approximation of the shafts of the two bones.

Fig. 241.



Fracture of the shaft of the radius. (Malgaigne.)

Fig. 242.

Fracture of radius and ulna, displacement upward of the lower fragment of the radius. (Malgaigne.)

The possible loss of supination in consequence of union with a rotatory displacement, the upper fragment being completely supinated by the biceps while the lower is kept partly pronated by the dressings, which was pointed out by Lonsdale, and has been spoken of in the section on fracture of both bones, is also to be borne in mind after fracture of the radius alone, especially if the seat of fracture is above the insertion of the pronator teres, and is to be met in the same manner, that is, by keeping the forearm supinated.

If the fracture is at or below the middle of the bone the tendency of the biceps and pronator teres is to draw the lower end of the upper fragment forward and inward, and that of the pronator quadratus and supinator longus is to draw the upper end of the lower fragment towards the ulna.

Overriding has been observed only when dislocation of the lower end of the ulna is associated with the fracture as in figure 242. Malgaigne indeed speaks of the change in angular displacement as a partial overriding, but he admits that the use of the term is perhaps improper.

The diagnosis is made by recognition of the displacement, if it exists,

of crepitation and abnormal mobility obtained by grasping the fragments with either hand and moving them upon each other or by placing a thumb upon the head of the radius and rotating the wrist gently.

The indications for treatment are the same as after fracture of both bones, except so far as the uninjured ulna may be utilized as a splint or as its dislocation may require more or less prolonged extension. If displacement exists the fragments should be pressed back into place as before described, and if the fracture is low down and the lower fragment is inclined toward the ulna it will perhaps be found easier to bring it back into line by drawing the hand forcibly downward and toward the ulnar side than by pressing the fingers in between the bones. Extension and counter extension at the wrist and elbow may be required to overcome dislocation of the lower fragment upward from the ulna.

The arm should be secured upon well-padded anterior and posterior wooden splints in the semi-pronated position if the fracture is below the middle and the tendency to displacement is slight, or upon a posterior splint and supinated if the fracture is high up. Dislocation at the lower radio-ulnar articulation or change in the direction of the lower articular surface of the radius may make it desirable to use a moulded splint that will include the hand and perhaps the lower part of the arm, or a long rectangular one for the purpose of extension and counter-extension, or to keep the hand inclined toward the ulnar side.

C. Fractures in the Vicinity of the Wrist.

1. Fracture of the Radius. Colles's Fracture.—Under this term are included fractures of the radius near the wrist, which, while differing from each other in many respects, have in common a characteristic deformity, and often a certain difficulty in making and maintaining reduction.

With possibly one exception, the outer half of the clavicle, the lower end of the radius is the part of the skeleton most frequently broken. While the fracture occurs at all ages, it is by far the most frequent in elderly women. It is very remarkable, and worthy of mention as a proof of the difficulty of diagnosis in fractures near a joint, as well as of the force of authority and tradition, that the real nature of this common injury which comes so frequently under the notice of all surgeons should not have been recognized, and that it should have been taken always for a dislocation of the wrist backward, until about one hundred years ago. The first mention of the injury as a fracture is generally attributed to J. L. Petit, but, I think, incorrectly, for I find no reference to it in his chapter on fractures, while the chapter on dislocation of the wrist contains a very good clinical description of it.

Pouteau[1] is the first author to describe it as a fracture and to point out the previous universal error in diagnosis. He describes its pathology, attributes its production to the violent contraction of the pronators, and gives its symptoms and treatment, adding that there is, perhaps, no fracture so easy to recognize at a glance. The fact that he includes in

[1] Œuvres posthumes, 1783, vol. ii. p. 251.

his description fractures of both bones does not, I think, diminish the credit due him for his recognition of the error of his predecessors and contemporaries. His view of the subject does not appear to have commended itself to his immediate successors, and, during the thirty years following its publication, only an occasional mention is made of even the possibility of such a lesion, and the common injury was still considered a dislocation.

The next writer upon the subject failed in like manner to impress his opinion upon his immediate contemporaries, and although justice was ultimately done him, and the fracture is now known widely by his name, the recognition did not come until after his death. Mr. Colles published his brief but accurate account of the fracture in 1814,[1] but Dr. R. W. Smith, writing in 1847,[2] says: "Subsequent authors have repeated what Mr. Colles had said upwards of thirty years since, but no writer (as far as I have been able to ascertain), not even the distinguished author of the Surgical Dictionary, has alluded to his account of the injury."

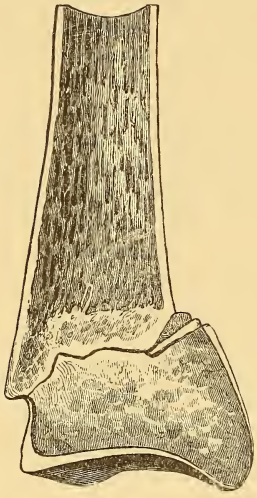
Sir Astley Cooper, in the second edition of his *Dislocations and Fractures of the Joints*, published in 1823, describes fracture of the lower end of the radius, and adds that he had seen this injury frequently, but did not understand its nature until taught by dissection; but he describes at the same time dislocation of the wrist, and evidently did not appreciate the full character and frequency of the fracture. In a subsequent edition he describes experiments made by himself upon the cadaver, in 1833, in which he produced the fracture by hyper-extension (extreme dorsal flexion) of the hand. The same failure to appreciate the character of the common injury which was coming so frequently under the care of every surgeon persisted, notwithstanding the publications of Pouteau and Colles, that of the former being entirely overlooked apparently, and that of the latter remembered only by the Dublin surgeons, who believed in the fracture and gave his name to it. But the misapprehension was not destined to last long; the great change which took place in the science of medicine at the beginning of the present century under the inspiration and guidance of the French physicians, the substitution of objective knowledge for dogma, of clinical and dead-house observation for pure speculation, made short work of this error. Dupuytren was the first to call attention to it and to impress it upon the profession; a post-mortem examination in 1820 showed him the real character of the injury, and his hospital service gave him the clinical opportunities that were needed for study and demonstration. A short period of doubt followed, and then, about 1830, the fact was universally accepted, and the second stage—that of discussion of details, which has lasted until the present time—was entered upon.

Mr. Colles, who had never had an opportunity to dissect a specimen of the fracture, speaks only of the symptoms and treatment. His only statement concerning the fracture itself is an incorrect one: "This fracture takes place at about an inch and a half above the carpal ex-

[1] Edinburgh Med. and Surg. Journal, April, 1814, vol. x. p. 182.
[2] Fractures in the Vicinity of Joints, Am. ed., p. 129.

tremity of the radius." We now know that, while the line of fracture may lie at the point he mentioned, it is usually much lower, and may be not further than a quarter of an inch from the articular edge of the bone. The average distance is differently estimated, possibly because some have measured from the articular edge of the bone and others from the styloid process; but the weight of testimony places it at from one-third to three-fourths of an inch above the articular border. In young people it sometimes follows the epiphyseal line. Its direction is usually transverse, but it may be oblique laterally or antero-posteriorly, and the lower fragment may be comminuted. The lower fragment is sometimes displaced bodily backward without crushing, as in figures 243 and 244.

Fig. 243.



Fracture of the lower end of the radius. Displacement backward. (R. W. Smith.)

Fig. 244.

Fracture of the lower end of the radius. Displacement of lower fragment backward.

Fig. 245.

Fracture of the lower end of the radius Angular displacement of the lower fragment backward with impaction. (R. W. Smith.)

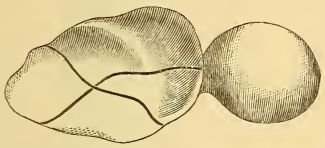
Sometimes the displacement is entirely angular, the lower fragment turning upon its anterior edge as upon a hinge, crushing or penetration with impaction takes place posteriorly and outwardly, and the articulating surface looks downward and backward instead of downward and forward as it does normally; at the same time the styloid process rises to a higher level. An extreme example of this displacement, with union, is shown in figure 245.

Specimens of recent fracture are not very common, and most of those we possess are open to the objection that the fractures have been caused by violence far in excess of that which causes the great majority of the fractures met with clinically, the patients having fallen from a considerable height, and having received also injuries that caused death within a short time thereafter. The most interesting specimens are those obtained from elderly patients who have received the fracture in the usual manner, that is, by a fall upon the ground while walking, and have then died

in a few days of an intercurrent affection, usually pneumonia. Such a specimen came into my possession in 1878; a woman, about fifty years of age, fell upon the sidewalk while walking, fractured the radius, and died within the week. The lower end of the bone was extensively comminuted for a distance of more than an inch, the articular surface being broken into four fragments (fig. 246).

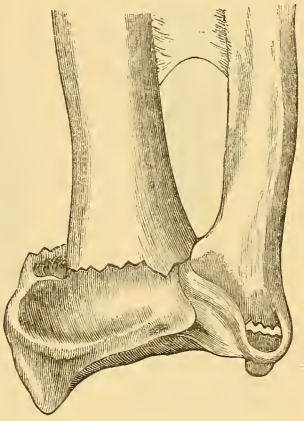
Malgaigne[1] describes and figures one observed by Maisonneuve; the patient was a woman seventy years old, and died of pneumonia a fort-

Fig. 246.



Comminuted fracture of radial articular surface.

Fig. 247.



Recent fracture of the radius, caused by a fall upon the hand. (Malgaigne.)

night after the accident. The periosteum was untorn on the posterior surface, and the styloid process of the ulna was broken off. The fracture was transverse, the displacement slight (fig. 247). The cause was a fall upon the hand.

Mr. Cameron[2] had an opportunity to dissect two similar cases, both in elderly men dying of pneumonia soon after the injury. In one the fracture was oblique downward and forward, so that in front it was one-fourth of an inch above the articular surface, and behind about one inch. In the other the fracture was transverse and about three-fourths of an inch above the articular surface. In front the fracture was hardly complete, and the periosteum was untorn, while posteriorly there was firm impaction with splitting, the lower fragment being split into three pieces, which were nevertheless held firmly and securely together.

A specimen obtained by Profs. McGraw and Walker,[3] of Detroit, deserves, I think, to be classed with the others, although the fracture was caused by a fall from a height of twenty-five feet. The wrist presented the typical deformity. On dissection there was found no displacement of the ulna; no ligament was broken. There was a transverse fracture of the radius half an inch above the lower articular margin. Anteriorly the fragments were separated about one-fourth of an inch; posteriorly the compact wall of the upper fragment was driven into the cancellated tissue of the lower one so firmly that some force was needed to disengage them (fig. 248). The dorsal articular rim was broken off and divided into three pieces. The patient was a man sixty-two years old.

In the specimens obtained after repair has taken place without reduc-

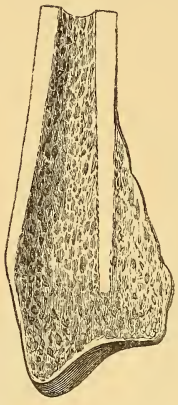
[1] Loc. cit., vol. i. p. 606; and Atlas, pl. x. figs. 2, 3, and 4.
[2] Glasgow Med. Journal, March, 1878, p. 97.
[3] Annals of Anatomy and Surgery, March, 1881, p. 116.

tion of the displacement the penetration of the posterior portion appears very marked (fig. 249), more so often than it really is. The appearance is due in part to the formation of callus upon the posterior face of the upper fragment (fig. 250), under the periosteum, which is stripped

Fig. 248.

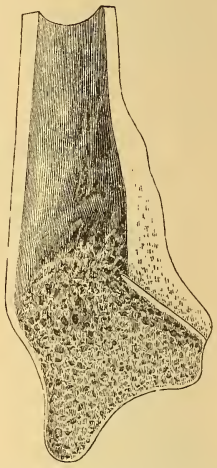
Impacted fracture of the lower end of the radius. (Annals of Anat. and Surg.)

Fig. 249.



United fracture of the radius. (R. W. Smith.)

Fig. 250.



Recently united fracture of the lower end of the radius. (R. W. Smith.)

up, or torn by the displacement or crushing, the "periosteal bridge," which is found almost always upon one side of a fracture, and in part to condensation of the interior spongy tissue during repair. This apparent penetration was insisted upon very strongly by Voillemier in support of his theory of the mechanism of the fracture, which he supposed to be usually a fracture by penetration, or an impacted fracture. Dr. R. W. Smith, criticizing Voillemier's theory, called attention to the outer callus, and, by comparing recently united specimens with those in which a longer time had elapsed since the injury, showed that a part at least of the penetration was only apparent, and was due to condensation of the spongy tissue in the direction of the outer shell of the upper fragment. But in denying penetration or impaction he seems to have overlooked *crushing*, that condensation of cancellous tissue under pressure which amounts to an actual loss of substance. It is undoubtedly true that in some cases the compact shell of the upper fragment, which may be reduced to the thickness of a sheet of paper, does not penetrate the lower fragment while preserving its own integrity, but an equivalent result is effected by the mutual crushing of both fragments along the line of fracture, and it is this which makes the angular displacement possible and the maintenance of reduction sometimes so difficult.

Mr. Callender[1] made an examination of all the specimens of this fracture, thirty-six in number, contained in the London museums, and found

[1] St. Bartholomew's Hosp. Reports, vol. i., 1865, p. 281.

the impaction not to exceed half an inch in any case, and usually much less; the angle between the fragment and the shaft measured on the posterior surface he found to average 156°, the extremes being 143° and 166°, and the length of the fragment on the same side to average four-fifths of an inch. There was no displacement in the direction of pronation or supination, as is so common after fracture of the shaft of the radius, but in some the fragment was displaced to one side or the other. He says: "In the greater number of cases the two bones [radius and ulna] have their mutual relations but little altered. I have met with only the following displacements:" 1. Fragment driven to the radial side with half an inch of shortening; the carpus and hand are inclined to the radial side and the ulna appears unnaturally prominent. 2. Dislocation of the ulna forward towards the pisiform bone. 3. Displacement of the fragment upward, outward, and backward with the formation of a new articular surface on the ulna by the growth of a half ring of bone upwards from the margin of the original articular surface. 4. Fracture of the ulna seven-tenths of an inch above its end, the lower fragment inclining outward towards the displaced radius. 5. Displacement of the ulna backward upon the inner dorsal surface of the radius, the fragment of the latter being also displaced backward and far to the outer side.

It has been both asserted and denied that there is also an angular displacement of the fragment about an antero-posterior axis, or upon the lower end of the ulna as a hinge, a displacement that carries the upper end of the fragment towards the ulna and raises the styloid process to a higher level. Prof. Gordon[1] says, that of 19 specimens examined by him the interosseous space was normal in 10 and only slightly diminished in the remaining 9. He found the greatest diminution in those in which the fracture was at a distance of more than an inch from the articular border. Elevation of the styloid process is established beyond question; it is one of the most familiar clinical symptoms and is found also in specimens, but apparently it is accomplished by the crushing of the tissue on the outer side of the bone and the production of angular displacement towards that side similar to the one already described as found upon the dorsal aspect. As a matter of fact, the articular surface of the radius is usually displaced so as to look outward as well as backward.

Among the lesions that may be associated with the principal fracture are: fracture of the ulna near its lower extremity, fracture of the styloid process of the ulna, rupture of the radio-ulnar and inter-articular ligaments, and perforation of the skin by the ulna. The first is not very common, and all the others are the consequences of momentary prolongation of the action or variation in the degree of the force which has caused the fracture. Nélaton thought fracture of the styloid process of the ulna occurred frequently, an opinion which Dr. Hamilton says is supported by the observations of no other writer, but quite recently Cameron (*vide supra*) has stated that this fracture existed in five specimens examined by him. Dr. Moore[2] has also found it in four or five cases,

[1] Fractures of the Lower End of the Radius. London, 1875.
[2] New York Medical Record, 1870, vol. v. p. 49, and vol. xvii. 1880, p. 305.

together with laceration of the inter-articular fibro-cartilage and displacement of the end of the ulna through the internal lateral ligament. He looked upon this displacement of the ulna, which he thought had not been before observed, as the key to the deformity and the cause of the difficulty of reduction so frequently met with, and believed that it existed in more than half the cases. A case almost identical in its pathology with the one that was the basis of Dr. Moore's first paper is published in the *Bulletins de la Société Anatomique*, 1839, vol. xiv. p. 190, and cases of compound dislocation of the ulna in connection with fracture of the radius are not very infrequent, Sir Astley Cooper's book alone containing four. Concerning the condition of the fibro-cartilage I can find but little that is positive, since the only sources of information are the autopsies of recent fractures. Neither Callender nor Cameron mentions its condition in the specimens of recent fracture dissected by them, although the former says of one in which there was only a slight amount of displacement, that "the periosteum was torn from the bone and the pronator quadratus muscle was lacerated and bruised," and of another, in which there was impaction on the dorsal and outer aspect to the distance of four-tenths of an inch, that "all the muscles and tendons around the seat of the bone-hurt [the fracture was seven-tenths of an inch above the articular border] were bruised and torn, especially the pronator quadratus, which was wrenched away with the periosteum from the bone, the latter, immediately below and for about two inches above the line of fracture, being completely denuded." He adds, "the wrist joint was uninjured," and the inference seems fair that the ligament was not torn.

It will be remembered that the cartilage is attached to the base of the styloid process of the ulna and that consequently the rupture of the ligament and the fracture of the process are the interchangeable consequences of the same force, traction upon the ligament through its attachment to the radius. Consequently, when the lower fragment is displaced upward the cartilage is put upon the stretch; if the displacement is increased the ligament or the process gives way, and as the carpus follows the fragment the internal lateral ligament, already weakened perhaps by the fracture of the process, yields and is drawn towards the outer (radial) side of the ulna; if the displacement is carried still further the ulna perforates the skin.

Experiments made by Sir Astley Cooper in 1833, showed "that it requires a much less degree of force to fracture the radius than to displace the extremity of the ulna, or to rupture any of its connecting ligaments," and Dr. Moore's experiments showed an equivalent fact, that rupture of the ligaments and fracture of the styloid process of the ulna took place only after fracture of the radius if the force (hyper-extension of the hand) were prolonged. These complications therefore must be considered the exception rather than the rule, and peculiar to the severer cases.

I have not met with the record of any case in which the radius projected through the skin, except after separation of the epiphysis; of this Bruns[1] collected five cases.

[1] Archiv für Klinische Chirurgie, vol. xxvii. p. 240.

A complication which, so far as I know, is entirely unique, is reported by Cameron, dislocation of the scaphoid forward. The patient was a man 32 years old, who fell from a height Feb. 27, 1877, and received a "well-marked Colles's fracture of the right radius." The middle and ring fingers were strongly flexed and the slightest attempt to extend them caused great pain. "A small bone or fragment of bone was felt lying under the skin in the middle line of the front part of the forearm, about an inch above the flexure of the wrist." Cameron cut it out with antiseptic precautions, and it proved to be the entire scaphoid bone. The patient made a good recovery and had a useful hand.

Dr. Rhea Barton,[1] of Philadelphia, described clinically a fracture which he said was very common, and which he supposed to be the detachment of the posterior border of the articular surface of the radius. It does not appear from his paper that he had ever had an opportunity to verify the diagnosis by examination. A few specimens of such a fracture, most of them, I believe, found in the dissecting-room and without history, are in existence, and the injury is known in America as Barton's fracture. Dr. Agnew (loc. cit., vol. i. p. 905) figures a specimen in which the fragment is much larger. It is perhaps hardly worth while to try now to change this name, but there are three good reasons why the injury should not be known as Barton's fracture: 1st, as Dr. Hamilton has said, and as a reference to the original article shows, the injury which Barton described clinically was not what he supposed it to be anatomically, but was the ordinary Colles's fracture; 2d, the lesion, as he supposed it to be, had been observed some years before his paper was published, and the specimen was presented by Lenoir to one of the Paris societies;[2] and, 3d, it deserves to be classed not as a variety of fracture, but as a complication of dislocation of the carpus backward. In Lenoir's case, which is described as a dislocation by Voillemier and Malgaigne, a narrow fragment of the posterior articular border had been broken off, remained attached to the capsule, and was displaced backward with the bones of the wrist.

An analogous case, dislocation of the carpus forward with detachment of the *anterior* border of the articular end of the radius and fracture of the styloid process, was reported, with the specimen, to the Socié é Anatomique,[3] by Letenneur. The patient was brought to the Hôtel Dieu May 7, 1838, having received this injury and also a fracture of the scaphoid bone of the other wrist, by falling into a ditch while intoxicated. Mr. Callender (loc. cit., p. 291) refers to a somewhat similar specimen, but one in which the fragment is much larger, in the following words: "The line of fracture is four-tenths of an inch from the end of the radius on the palmar surface, but on the dorsal passed into—along the edge of—the articular facets."

Other irregular fractures, too rare to be classified or systematically described, may be conveniently mentioned here. 1. An oblique fracture

[1] Medical Examiner, 1838, p. 365.

[2] This fact is mentioned by Voillemier, in the Archives Générales de Médecine, 1839, vol. vi. p. 402, and by Malgaigne. The Society referred to is probably the Société Anatomique, but I have failed to find mention of the specimen in its Bulletins.

[3] Bulletins, vol. xiv. p. 162.

running downward and inward and detaching the styloid process of the radius with more or less of the articular portion; the larger the fragment the more closely will the symptoms resemble those of Colles's fracture.

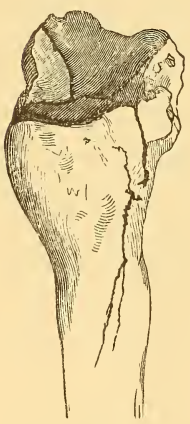
2. A condition which is the direct opposite of that constituting Colles's fracture; the lower fragment is inclined toward the palmar side, and the crushing is also on that side. Mr. Callender (loc. cit., p. 289) reports such a case caused by forced flexion of the hand in a fall upon it; there was a well-marked prominence on the dorsum of the forearm about three-fourths of an inch above the wrist-joint, and opposite it on the palmar surface was a considerable depression. The lower fragment of the radius was inclined at an oblique angle to the palmar surface, and projected at the wrist. No crepitus. Reduction could not be effected. Ten months later the deformity persisted, with good rotation, exaggerated flexion, and inability to extend the hand beyond a straight line with the forearm.

He mentions also two specimens, one in the museum of Westminster Hospital, the other at St. Bartholomew's, which show the corresponding displacement with union. In one the styloid process of the ulna was broken and the lower fragment of the radius displaced forward and outward, especially in the latter direction, with penetration on the palmar surface to the depth of more than three-tenths of an inch. In the other the line of fracture is rather more than an inch above the end of the bone; there is a prominent angle on the dorsal aspect in the line of the fracture and an elevation of new bone on the corresponding part of the palmar surface; the triangular fibro-cartilage was almost completely separated from the radius.

R. W. Smith (loc. cit., p. 162) describes and figures a similar case, in which also the fracture was caused by a fall upon the back of the hand, and Dr. Hamilton thinks he also has seen one.

Still another instance, of very exceptional character in its mode of production, but apparently about the same anatomically, is quoted by Callender as a "green-stick" fracture. Wm. G., aged 14, went to the Polytechnic and was there galvanized; the shocks were violent and he struggled to let go, but for a time was unable to do so. His wrists became painful, and the next morning he was unable to work. A week later he came to the hospital. "Either radius close to the carpal end was bent at a considerable angle to the shaft, so that, on the dorsum, there was on either forearm a well-marked prominence, greater on the right. All his other bones were natural." He remained under the care of Mr. Stanley for some time, and by degrees recovered good motion at the wrists but retained an unsightly deformity. It was thought that the bones had been partly broken or bent above the epiphysis during the violent muscular efforts.

Fig. 251.



Fissured fracture.

3. Longitudinal fracture or fissure of the end of the bone (fig. 251). Dr. Bigelow[1] reported one case

[1] Boston Med. and Surg. Journal, 1858, vol. lviii. p. 99.

and referred to a second. There was a star-shaped crack on the articular surface without displacement, and slight corresponding cracks in the shaft for more than an inch above. At first there was only lameness at the wrist, but after several days there were swelling and tenderness, the persistence of which led Dr. Bigelow to make the diagnosis. He had had a similar case two years before, with the same symptoms, but less extensive injury to the bone.

The *cause* of Colles's fracture is usually a fall upon the palm of the hand, and in the great majority of cases the fall is only to the ground while walking. This is true of almost all cases in which the patients are somewhat advanced in life; in the younger ones the violence is usually greater, as a fall from a ladder or tree. The only instance of fracture by muscular action is the one mentioned just above.

The mechanism by which the fracture is produced has been almost from the very beginning and still is the subject of much discussion. Three theories have been advanced: 1st. Fracture by penetration or crushing; the cancellous tissue is crushed or comminuted between the carpus and the diaphysis. 2d. Fracture as in other bones by decomposition of the force and yielding at the weakest point. 3d. Fracture by cross-strain exerted through the anterior ligament in exaggerated and forced dorsal flexion (hyper-extension) of the hand. Each is partly, none exclusively, true.

There are two principal varieties of the first: one in which the lower fragment is comminuted, and one in which there is deep reciprocal penetration of the two fragments with but little transverse displacement. The former is the more common, and an exceptional degree of force is not required to produce it, a fall upon the palm of the hand while walking is sufficient in an old person. The latter is probably rare, but it has been demonstrated by autopsy.

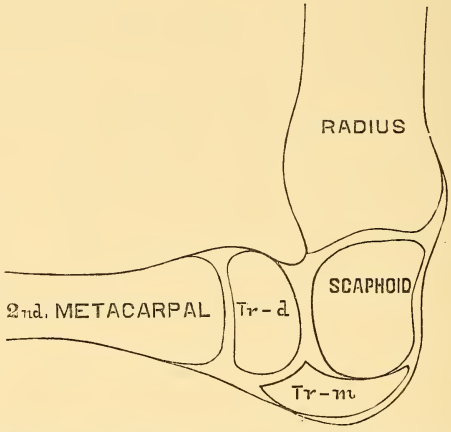
The second theory is, in my judgment, true of the great majority of cases, and it can be best proved negatively, by disproving the third theory. According to it the force is received, in a fall, upon the palm of the hand close by the wrist, at a point which is in the direction of the long axis of the radius, and is, therefore, transmitted directly through the carpus to the articular surface of that bone. The radius is not straight, and, furthermore, the direction of the force may be inclined more or less to the axis of the bone; the force is decomposed in the usual manner and the fracturing strain is exerted by one of its components. The bone breaks at its lower end, because that is the part least fitted to withstand the strain. The momentary continuation of the force either displaces the lower fragment backward or crushes its posterior portion with or without impaction or comminution. The fracture can be produced upon the cadaver by placing the palm of the hand upon the table, holding the radius upright, and striking a heavy blow upon its upper end.

According to the third theory a cross-strain is exerted upon the end of the bone through the anterior ligament of the wrist; the force is thought to be received upon the palm of the hand at a point that lies posterior to the posterior border of the end of the radius, the hand is bent back, the ligament is put upon the stretch, and the bone is broken

by avulsion. The theory seems to have originated in experiments upon the cadaver. The earliest recorded experiments in this direction were those already alluded to which were made by Sir Astley Cooper in 1833, but not published until several years afterwards, the earliest publication appears to have been by Bouchet[1] in 1834. The experiment is a simple one ; it is sufficient to interlock the fingers with those of the cadaver and force the hand backward. Usually a transverse fracture is produced within half an inch of the articular surface of the radius, but sometimes the anterior ligament yields. If the action is continued after the fracture has taken place, the inter-articular ligament and the styloid process of the ulna are the next to yield. There is no doubt, therefore, that the fracture can be produced in this way, and there are a few clinical cases in which this was unquestionably the mode of production. But, with the exception of these few cases, in which the mode of action of the violence was distinctly exceptional, there is nothing but the dead-house experiments to support the theory.

In the first place, there is good reason to think (the point is not open to absolute proof) that the violence in a fall is not usually received at a point on the palm of the hand posterior to the line of the radius ; it is received at the base of the thumb, at a point corresponding to the trapezium. When the hand is bent backward the motion takes place between the first and second rows of the carpus ; the first row remains in place and the second row swings around until it comes almost into contact with the radius, as shown in figure 252. This figure represents a section

Fig. 252.



Section in the long axis of the radius ; the hand in dorsal flexion. Tr-m, trapezium : Tr-d, trapezoid.

made through the radius and the second metacarpal bone and traversing the point upon the palm which receives the blow in a fall, and as the position is that of extreme physiological dorsal flexion it is evident from it that no cross-strain can be exerted until after this limit has been passed

[1] Thèse sur les Luxations du Poignet. Quoted by Malgaigne.

and the second row of carpal bones have obtained a bearing upon the radius. Before this can take place the flexor muscles must be overpowered, and that is a fact which I think has not been taken properly into account in reasoning from the results of experiments. The strain does not come upon the ligament unless the hand is caught under the body in the fall and bent far back. Ordinarily the hand is not bent back even to a right angle, not even far enough to make the anterior ligament of the wrist tense, much less to exert a fracturing strain through it. Moreover the resemblance between the fractures produced experimentally by over-extension and those caused by falls during life is by no means so close as has been asserted.

Finally, there are cases on record in which it appears to be proved that a fall upon the back of the hand produced the characteristic fracture and displacement of the lower fragment backward. In a case observed by Prof. Cameron (loc. cit., p. 97) the patient, an elderly woman, fell "upon the back of her wrist, the fist being kept shut in order to retain a grasp of some small object held in the hand." The most reasonable explanation of this identity of result in opposite positions of the hand appears to me to be obtained by rejecting the theory of cross-strain and accepting the second one.

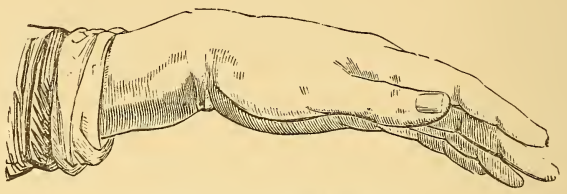
Muscular contraction, which was thought by Pouteau to be the sole cause of the fracture, and has since been invoked by others, is now looked upon only as an adjunct of uncertain importance. The only recorded case in which it appears to have been the sole efficient cause is the one already mentioned of the boy in whom the fracture followed the muscular contraction excited by a strong galvanic current. The mechanism in this case appears to have been fracture by exaggerated palmar flexion, and, considering the unusual circumstances of this case and the weakness of the extensor muscles as compared with the flexors, there is not the slightest reason to think that the ordinary fracture can be due to preponderant action of the extensors. The combined action of both sets of muscles in the spasmodic effort to arrest a fall unquestionably supplements that of the violence received upon the palm, and their tonic contractility tends to keep up the displacement when there has been loss of substance by crushing of the bone; but in an uncomplicated transverse fracture without crushing the tendency to reproduction of the deformity by the action of the muscles after its reduction is slight, or even absent.[1]

The *symptoms* are marked and characteristic, but crepitus and abnor-

[1] Lack of space prevents detailed reference to, and discussion of, the views and arguments advanced by others upon this question of the mechanism of Colles's fracture. The literature of the subject is voluminous. The reader is referred, in addition to the works already quoted, especially to papers and discussions by Drs. Hamilton, Pilcher, Levis, and others in the N. Y. Medical Record, 1878 to 1881, *passim*, the Philadelphia Medical Times, 1881, and the Annals of Anatomy and Surgery, March, 1881, to a monograph by Prof. Gordon of Belfast (Fractures of the Lower End of the Radius, London, 1875), and to a thesis by Schmit (Des Fractures de l'Extremité inférieur du Radius, Paris, 1878). Drs. Pilcher, Gordon, and Schmit are advocates of the theory of fracture by cross-strain or avulsion. Dr. Pilcher has in addition called especial attention to the periosteal bridge upon the dorsal surface, to the part taken by the "oblique anterior carpo-ulnar fasciculus" in controlling the direction and extent of the displacement, and to the "wedge-action" of the carpal bones in caus ing comminution.

mal mobility, so common in other fractures, are rarely present in this. The most striking part of the deformity is a deviation backward at the wrist of the long axis of the forearm, so that when viewed from the radial side its appearance is like that represented in fig. 253, and was

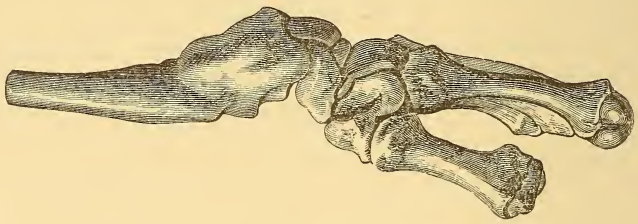
Fig. 253.



Deformity in Colles's fracture.

aptly compared by Velpeau to the outline of a silver fork, a comparison which has survived in the name "silver fork fracture," by which it is frequently known. The cause of this change in the outline, so far as it is due to the position of the fragments, is shown in fig. 254. The dis-

Fig. 254.



Colles's fracture. Union with persistence of displacement. (Smith.)

placed carpal fragment forms the prominence on the dorsum, and the lower end of the upper fragment is marked by the prominence on the anterior aspect. If the outer portion of the lower fragment is displaced upward to a much greater extent than the inner portion, the hand is noticeably deflected to the radial side, and the lower end of the ulna is prominent.

If the surgeon marks the positions of the styloid processes by pressing the end of a finger into the side of the joint below and against the end of each, he will see that that of the radius has risen, so that instead of being about a quarter of an inch lower (nearer the hand) than that of the ulna, as it usually is, it has risen to the same level, or even above it.

If now the wrist is flexed and pressure is made upon the dorsum of the forearm just above the prominence, the tendons of the radial extensor muscles can be felt as a sort of cord stretching across from the upper to the displaced lower fragment; this sign was pointed out by Velpeau, but it is lacking if the lower fragment is not displaced bodily backward.

The swelling upon the anterior surface of the forearm is quite marked, and is sharply rounded off towards the wrist where it adjoins the depres-

sion corresponding to the dorsal prominence. It is produced in part by the prominence of the lower end of the upper fragment, which results from the displacement of the lower fragment and the carpus, and in part by an effusion within the sheaths of the tendons, which is prevented by the annular ligament from showing itself nearer the wrist. The presence of this effusion can be readily demonstrated by placing the fingers of one hand upon the patient's palm and pressing with those of the other upon the prominence in the forearm; the wave can be felt to pass from one to the other.

Crepitus and abnormal mobility may sometimes be obtained by the manœuvre recommended by Colles: "Let the surgeon apply the fingers of one hand to the seat of the suspected fracture, and, locking the other hand in that of the patient, make a moderate extension until he observes the limb restored to its natural form; so soon as this is effected let him move the patient's hand backward and forward, and he will at every such attempt be sensible of a yielding of the fractured end of the bone." In communicating these movements to the hand, it is well to grasp the lower fragment between the thumb and fingers to insure and recognize its movement with the hand. In some cases the reduction is permanent, in others the deformity returns as soon as the extension ceases.

Pressure below the ulna on the inner side of the wrist is painful, also along the line of fracture on the dorsum of the radius. The hand is held in the semi-prone position, and rotation is painful.

The *diagnosis* is made by recognition of the above signs and symptoms. In difficult cases, fat people and children without displacement, it may be made upon the existence of a well-defined transverse line of tenderness on pressure on the dorsum of the radius, deepening of the transverse folds on the palmar aspect of the wrist, loss of power in the limb, and history of the case.

A sprain or contusion may be mistaken for a fracture if the limb has been broken previously and has united with deformity, for it will present many of the physical and functional signs. The question therefore should always be asked whether the wrist has suffered a previous injury.

Course and Prognosis.—Firm union between the fragments may be expected in a month, and failure of union, according to Dr. Hamilton, is unknown. The course is uneventful, except for the inflammatory symptoms of the first week; these may be severe, and if the bandages are not properly looked after strangulation and sloughing may follow. The prognosis with reference to deformity depends, of course, upon the completeness of the reduction and retention. As a rule, permanent deformity after fracture in youth is slight or entirely absent; but in old people the case is different, either because the original displacement is greater, or because crushing and comminution make complete reduction and retention practically impossible.

The prognosis with reference to function is somewhat better, since the persistence of even marked displacement does not necessarily entail disability. The range of motion at the wrist may be somewhat restricted, and yet may be wide enough to answer all purposes, and a change in the direction of the articular surface is still compatible with free and painless motion. Rigidity of the wrist and fingers usually persists for some

weeks, or even months, and in exceptional cases, in the old and rheumatic and in those where there has been much inflammation of the sheaths of the tendons and of the wrist-joint, it may persist for years. I have seen two cases in which the hand was practically useless a year or two after the receipt of the injury. There was much deformity in one of them. This rigidity of the fingers is due in part to their prolonged immobilization and in part to inflammation within the sheaths of their tendons in the forearm.

The possible arrest of the growth of the bone after separation of the epiphysis deserves mention, although it is an exceptional consequence of the injury. It has an especial importance at this point because of the presence of two parallel bones; if the growth of the lower end of the radius is arrested while that of the ulna continues, a noticeable deviation of the hand towards the radial side must result.

Treatment.—Complete reduction of the displacement is, of course, essential to prevent permanent deformity. The ease with which it can be accomplished varies greatly in different cases. The method quoted above from Colles is sometimes sufficient, traction upon the hand with some direct pressure upon the fragments; in other cases forcible pressure must be made upon the fragments, the forearm is grasped with the fingers upon the palmar prominence and the thumbs upon the dorsal one, and the pieces are pressed into line. Dr. Pilcher thinks the untorn periosteum of the dorsal side is a potent obstacle in many cases to reduction by direct pressure, because it holds the lower fragment tilted backward, and he recommends that reduction should be made by first bending the wrist backward so as to relax this band of periosteum, then making slight traction upon it in the line of the forearm, and finally moderate pressure upon the dorsum of the lower fragment as the hand is straightened.

Splints in great variety have been devised with the view to avoid the characteristic deformity which is found so frequently to have taken place or to have persisted during treatment. The theory upon which many of them have been constructed is that the essence of the deformity lies in the shortening of the outer side of the radius, in the ascent of its styloid process, and that this can be met by extreme adduction of the hand; for a similar reason flexion of the wrist is also recommended. The first embodiment of this principle was in Dupuytren's ulnar splint, a metal rod made fast to the inner side of the forearm and curving away from the hand so that the latter could be drawn towards that side by tapes carried around it under the thumb and made fast to buttons on the splint. The idea survives in the "pistol-shaped" splints, in all, in fact, in which the portion of an anterior or posterior splint which corresponds to the hand is deflected towards the ulnar side. The idea is one which is suggested very naturally by the deformity, the error lies in the inference that effective traction can be made through the loose ligaments of the joint. There is no difficulty in modifying the position of either condyle of the humerus or femur by bending the forearm or leg to the opposite side if the lateral ligaments remain untorn, because the bond is close and firm and allows no lateral motion, but at the wrist the case is very different, the ligaments are loose and there is free motion of the joint in every

direction. The ligament is not put upon the stretch until the limit of the range of motion is reached and the opposing muscles are drawn out to their full length. Although theoretically the ligament should then be efficient to prevent the ascent of the fragment if the lateral motion of the wrist were that of a hinge-joint, yet, as Drs. Hamilton and Cameron have pointed out, this is not so in fact; there is no fixed point of support upon the ulnar side to make the strain effective, and the result is quite as much to force the wrist and the end of the radius outward away from the ulna, as to draw the fragment down. Those who favor an extreme angular position of the hand do not attach sufficient importance I think to the fact that the opposing muscles are thus put upon the stretch, and that when the hand is fixed in its position their contractility is exerted upon the lower fragment of the radius exactly as if their tendons were attached to it, and as this contractility is increased by their extension its tendency to displace the fragment directly upward is increased in like manner and cannot be efficiently opposed if there has been loss of substance by crushing or if the fracture is oblique backward and upward. The rule which is good elsewhere is equally good here, the muscles should be relaxed.

If the line of fracture is transverse and there is no crushing not much is needed to keep the fragment in place after it has once been properly reduced; and if, on the other hand, there is much loss of substance by crushing or comminution or if the line of fracture is oblique the artificial outside support which is then needed to prevent displacement cannot be given, because the fragment is too small to be effectively acted upon by a splint.

The indications are of two kinds: to immobilize the fragments, and to allow passive and voluntary movements of the fingers in order to prevent or diminish their subsequent stiffness. The tendency is towards displacement of the lower fragment backward, and the splints need therefore to be so adapted as to make pressure in the antero-posterior direction. One of the earliest devices is one that is now in general use; anterior and posterior splints so padded that the former presses upon the upper fragment and the latter upon the lower one. The details may vary within certain limits, but a convenient form is as follows:—

Two splints are made of light wood of a uniform breadth equal to the largest diameter of the forearm; the anterior one should be long enough to extend nearly from the bend of the elbow to the metacarpo-phalangeal joints, the other from the corresponding height to the back of the carpo-metacarpal joint. These should be padded with cotton, wool, or hair as described in the Chapter on Treatment, the padding being especially thick on the anterior (palmar) splint at the part which corresponds to the lower inch of the upper fragment and on the lower end of the posterior splint so as to make pressure on the lower fragment. These splints are placed directly against the skin and secured by two strips of adhesive plaster, one at either end. Care must be taken to have the anterior splint short enough to let the fingers bend over its end easily and not to make annoying pressure at the elbow. The posterior splint must not encroach upon the back of the hand (fig. 255).

The addition of a roll of bandage an inch and a half in diameter

secured to the lower end of the anterior splint by stitching or adhesive plaster in an oblique direction so that its long axis is inclined upward

Fig. 255.

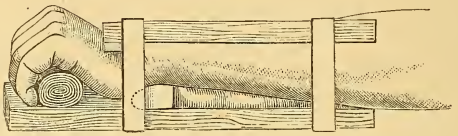
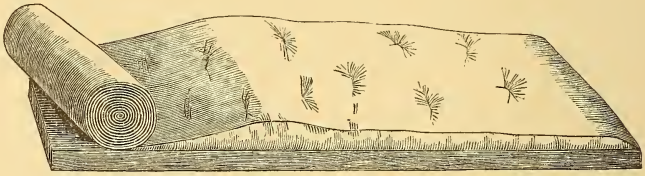


Diagram to show relative positions of the splints. (The splints and pads should be placed an inch nearer the elbow than is shown in the figure.)

and to the ulnar side increases the comfort of the patient by supplying a convenient support for the flexed fingers and thumb (fig 256). The

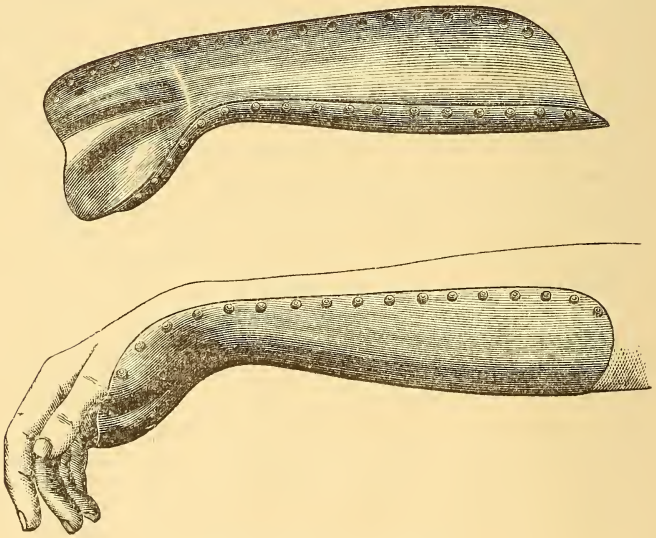
Fig. 256.



Anterior splint for Colles's fracture.

same support for the hand and fingers is obtained in some other splints by modelling them suitably in wood or by padding. The roller fur-

Fig. 257.



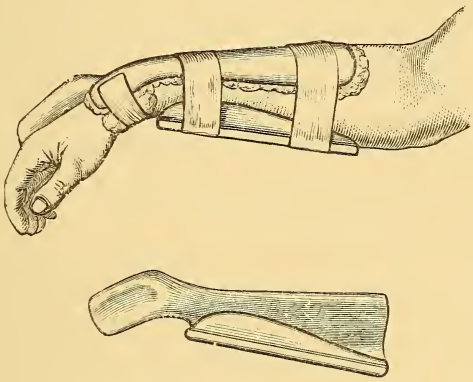
Levis's splint for Colles's fracture.

nishes a convenient means of extemporizing the splint and is associated in this country with the name of the late Dr. Hays, of Philadelphia.

Dr. Hamilton inclines the lower end of the anterior splint towards the ulnar side so that the hand is kept adducted. He does this not with the idea of thereby exerting any traction upon the lower fragment but merely to keep the radius more completely in view in order to recognize more readily the condition and situation of the compresses and pads. Dr. Levis of Philadelphia has devised a convenient splint of tin moulded to fit the irregularities of the palm, and curved to match the anterior curvature of the radius (fig. 257).

Gordon's splint (fig. 258), a much more elaborate one, some of the features of which are based upon arguments that I do not understand,

Fig. 258.



Gordon's splint for Colles's fracture.

is apparently in general use in Ireland and is said by Mr. Bryant to have found favor. A detailed description is unnecessary since the splint must be obtained from an instrument maker.

The forearm must be supported in a sling, and the patient should be instructed to move the fingers frequently.

Some surgeons, depending upon the slight tendency to recurrence of the deformity after complete reduction, discard splints entirely in the hope of thereby diminishing the subsequent rigidity of the fingers, a practice of doubtful propriety, I think, unless the patient is confined to the bed with the forearm and hand immobilized upon suitably adjusted pillows. I have seen several fractures treated successfully in this latter way in Gosselin's service at La Charité. Dr. Moore who, as has been said, considers dislocation of the ulna the common and most important part of the lesion, dresses with a small cylindrical pad about two inches long secured against the anterior face of the ulna by a strip of adhesive plaster wrapped very tightly about it and the lower end of the radius.

All are agreed concerning the value of complete reduction, which should be made if necessary with the aid of anæsthesia. This once thoroughly accomplished makes subsequent treatment, except immobilization of the limb, in many cases comparatively unimportant. The bandages should not be tightly applied at first, they must be frequently inspected during the first day or two and loosened if necessary. If the

reaction is severe the patient should be put to bed, the arm placed on a pillow, and local treatment used to combat the inflammation.

Finally, it must be remembered that it is often impossible, on account of the crushing, comminution, or impaction, to reduce the displacement completely or to maintain the reduction, and that in such cases permanent deformity of the parts is inevitable.

The question sometimes arises whether deformity, persisting for some time after the injury and the result of an error in diagnosis or of failure of treatment, can be corrected. Among Dupuytren's earliest cases were three of this kind, and he succeeded in overcoming the deformity by steady forcible traction and pressure upon the fragments on the 20th, 29th, and 30th days after the receipt of the injury, the patients being respectively 69, 10, and 13 years old. Dr. J. L. Little[1] has recently treated a case successfully by refracture six weeks after the original injury. The patient was a woman 30 years old, and there were much deformity and pain.

2. Fractures at the Wrist other than Colles's.—Some fractures of the wrist which, while not entitled to classification with Colles's fracture, yet bear a certain resemblance to it, have been already described with such details as are needed.

Fracture of the Styloid Process of the Radius alone is rare. Dr. Hamilton quotes a case treated by Dr. Jas. C. Hutchison in which the fracture was caused in a boy 14 years old by a fall from a height of thirty feet. There was a second fracture at the junction of the lower and middle thirds. The fracture of the styloid process broke off a fragment that included about one-fifth of the articular surface, and this fragment was drawn up on the posterior surface to a distance of one and a half inches by the supinator longus. The position of the hand was the same as in Colles's fracture. An attempt to draw the fragment into place by means of a compress and adhesive plaster was unsuccessful; the fragment united in its new position but the movements of the wrist were not impaired and the power of rotation soon returned.

Dr. Hamilton was consulted in another case four months after the fracture had taken place. The fragment was tilted forward and carried slightly upward by the action of the supinator longus and was movable. The form of the wrist was natural and its movements unimpaired.

Dr. Agnew speaks of a *combination of Colles's fracture with fracture of the posterior articular border* and says there is a fine specimen of it in the collection of Prof. John Neill.

Of *transverse fracture* of the radius just above its carpal surface *with displacement of the fragment forward*, which has already been spoken of as sometimes produced by a fall upon the back of the hand, it needs only to be said that the diagnosis is made by attention to the position of the styloid process with reference to the carpus and the ulna and by recognition of the line of limited tenderness if mobility and crepitation cannot be obtained. The treatment should be the same as in Colles's

[1] N. Y. Med. Record, March 4, 1882, p. 245.

fracture, except that the position of the pads should be changed to meet the different displacements.

Fracture of the styloid process of the ulna, a frequent accompaniment of Colles's fracture, is sometimes observed separately as the result of direct violence. In addition to the usual symptoms of pain and swelling, mobility of the process could probably be recognized by direct manipulation or by abduction of the hand. Dr. Agnew says some deformity is likely to remain, and that in the only case he has seen the union was fibrous. He advises treatment upon an anterior splint with the hand inclined towards the ulnar side and in dorsal flexion so as to relax the extensor carpi ulnaris.

Fracture of both bones near the wrist is occasionally seen, and is said to resemble dislocation of the wrist backward. The diagnosis is made by attention to the relations between the styloid processes and the carpus and hand. Treatment as in Colles's fracture.

In *compound fractures*, which are usually by direct violence, every effort should be made to avoid amputation. Good results have been obtained by excision of the lower end of the ulna alone and of both bones.

CHAPTER XXIII.

FRACTURES OF THE CARPUS AND HAND.

1. Fractures of the Carpus.

Simple fractures of the carpal bones appear to be very rare. Only a few cases have been reported in which the nature of the injury was shown by direct examination, and I have met with only one in which the diagnosis was made during life. As the symptoms are very obscure it is possible that the injury may be more common than is supposed, and may frequently pass unrecognized. The number, size, and relations of the bones are such that they can be broken only by direct violence, as a blow, the passage of a wheel, or a fall upon the hand, or by traction (avulsion) in forced dorsal flexion or displacement. It occasionally happens in experimental fracture of the lower end of the radius that some one of the carpal bones is broken, and the same complication has been observed clinically. In a case of fracture of the lower end of the radius observed by Dr. Wm. Hunt,[1] of Philadelphia, the semilunar bone was broken transversely, one part being displaced backward with the carpus and the fragment of the radius, the other remaining attached to the unbroken anterior border of the radius by the anterior ligament.

Bérard[2] refers to two cases observed by Cloquet, in which fractures of the carpus were caused by a fall upon the hand from a height; both remained unrecognized until after the death of the patients from other injuries received at the same time. Malgaigne quotes from Jarjavay a fracture of the scaphoid produced in the same way; and another, also of the scaphoid and caused by a fall into a ditch, was reported by Letenneur.[3]

In a case quoted by Polaillon,[4] the diagnosis was made during life. The patient, a young and vigorous workman, fell from the second story of a house, and struck upon his feet and right hand. Robert examined him and could find no signs of fracture of the radius or ulna, but by grasping the styloid processes firmly with the fingers of one hand and the wrist with the other, and moving the latter backward and forward he felt a crepitus which was not transmitted to the radius and ulna.

The only symptom which could make the diagnosis possible is crepitation, and it might be very difficult to determine whether this had its origin in the carpus or in one of the adjoining bones.

[1] Annals of Anat. and Surg., March, 1881, p. 110.
[2] Dict. en 30 Vols., art. Main, p. 524.
[3] Bull. de la Société Anatomique, vol. xiv. p. 162.
[4] Dict. Encyclopédique, art. Main, p. 50.

The treatment would consist in immobilization of the wrist for two or three weeks, and it is probable that partial ankylosis would result.

2. Fractures of the Metacarpal Bones.

While simple fracture of a metacarpal bone is not a very common accident, still it is not so rare as some authors have inferred from hospital statistics. Malgaigne found 16 cases in a total of 2377 fractures of all kinds treated at the Hôtel Dieu, a percentage of 0.67 ; Polaillon 64 cases in a total of 5517 fractures treated in the Paris hospitals during the years 1861–2–3, a percentage of 1.16, while the combined tables of hospital and dispensary practice in Chapter I. give 104 cases in a total of 4310 fractures, a percentage of 2.41. Of Polaillon's 64 cases, 57 were men, only two were old, and none were infants.

The same author tabulated 102 cases according to the bone affected, with the following result :—

1st	metacarpal,	8	fractures.
2d	"	16	"
3d	"	34	"
4th	"	35	"
5th	"	9	"

In 14 cases two bones were broken, and in 3 cases three bones. There appears to be no notable difference in the frequency with which different portions of the bone are broken. A very few cases of probable separation of the distal epiphysis have been recorded, one by Malgaigne, one by Hamilton, and one quoted by Polaillon from a thesis by Pichon, the ages being 9, 8, and 12 years respectively. There was failure of union in Malgaigne's case, but without disturbance of function when last seen, thirteen years after the injury. Experiments upon the cadaver have shown that the principal varieties of fracture common to long bones can be produced in the metacarpus, and that those due to direct violence are usually toothed and transverse, those due to indirect violence more frequently oblique than transverse. The usual displacement is angular, the head of the bone being drawn forward towards the palm, and the apex of the angle being directed backward, and at the same time the fragments may override longitudinally notwithstanding the attachments which bind them to the adjoining bones.

The *cause* may be direct or indirect. When direct it is a blow upon the back of the hand, a fall or blow upon its side, or a crushing force, the hand being caught between two solid bodies. The first, second, and fifth metacarpals are the ones most frequently broken by direct violence. A very exceptional variety is one mentioned by Sanson,[1] and quoted by most subsequent writers. He says he had seen several times a fracture caused by the reaction upon the hand of the stick with which a blow was struck.

The commonest indirect cause is violence received upon the distal end of the bone in the direction of its long axis, by which its normal curve

[1] Dict. en 30 Vols., art. Main, p. 525.

is exaggerated and fracture produced, as in a fall upon the knuckles or a blow with the fist. Lonsdale reported a case in which fracture of the third metacarpal was caused by a fall upon the end of the outstretched middle finger. In a case reported by Dupuytren, the third metacarpal bone was broken by being bent backward in a trial of strength, the contestants trying to force each other's wrist back, their fingers interlocked and the ends pressing upon the back of the other's hand. Velpeau saw the same bone broken by traction upon the index and middle fingers with some twisting.

The *symptoms* are the deformity due to the displacement of the distal fragment, abnormal mobility, crepitation, pain, and inability to move the fingers. The deformity consists usually in a projection upon the back of the hand at the seat of fracture and in the prominence of the head of the bone upon the palm, and sometimes in shortening, which, although slight, can be easily recognized by comparison with the corresponding finger of the other hand. Abnormal mobility and crepitation may be found by flexing and extending the corresponding finger and at the same time making pressure upon the palm at the supposed seat of fracture, so as to make the fragments prominent behind. The peculiarity of the pain is that it can be suddenly and sharply increased by pressing the finger towards the carpus; this was pointed out by Verneuil and is insisted upon by him as almost pathognomonic.

The course of the fracture is usually simple, and ends in consolidation in the course of three or four weeks. The complications which occurred in the eighty-one cases collected by Polaillon were inflammation of the carpo-metacarpal joint in one, union with marked displacement, fusion of adjoining bones when both were broken in one, deviation of the extensor tendons by a voluminous callus in one, and failure of union in three. In a case reported by Dr. Hamilton, fracture of the second metacarpal, caused by striking with the fist, was followed by suppuration, complete ankylosis of the wrist, and partial ankylosis of the fingers.

Treatment.—The first indication is to prevent a too severe inflammatory reaction if it threatens, and with this object the hand must be kept at rest in an elevated position and treated with hot fomentations or cold, according to the peculiarities of the case or the preferences of the surgeon.

If there is no displacement or tendency thereto, a simple immobilizing dressing of cotton, bound on snugly with a roller bandage, is sufficient, the fingers being left free to prevent their stiffening.

A very ancient method, one that has always found favor, is to fill the palm with a mass of tightly packed cotton, or some similar substance, or a ball over which the fingers are closed and fastened down with a bandage or adhesive plaster. The flexion of the finger over the firm mass tends to draw the knuckle downward, and thus prevent shortening. The support furnished by the adjoining bones is an additional aid against displacement, and the back of the hand can be left partly uncovered for inspection.

In fracture of the third and fourth metacarpals the hand may be bound upon a dorsal or palmar longitudinal splint suitably padded and fastened

with a roller, but this plan is unsuited to fractures of the second or fifth, because the circular compression exerted by the bandage tends to cause lateral displacement. Malgaigne used narrower splints, crossing the band transversely in front and behind at the seat of fracture, and made fast by binding the projecting ends together.

If continuous extension seems necessary to overcome a tendency to displacement, the hand and forearm can be placed upon a long splint, which is made fast at the elbow for counter-extension and projects well beyond the fingers. An elastic cord is attached by means of adhesive plaster and a bandage to the finger corresponding to the broken bone, and fixed with suitable tension to the projecting end of the splint.

Sabatier sought to meet the same indication by fastening the finger to the adjoining ones with adhesive plaster.

Dr. Hamilton saw a case of compound fracture of the second metacarpal bone about three-fourths of an inch from its carpal end, in which the broken end of the proximal fragment was directed backward. Dorsal flexion of the wrist made reduction easier, and the hand was kept in this position by appropriate splints during treatment. Union took place with some backward displacement.

Fracture of the first metacarpal is to be treated like fracture of a phalanx.

3. Fractures of the Phalanges.

In the great majority of cases these fractures are due to direct violence, and in consequence they are frequently compound, or at least accompanied by laceration or bruising of the soft parts. A few cases have been reported of fracture by indirect violence, as in a fall or blow upon the end of the finger, or by having the finger caught and fixed while the hand continued to move.

The first phalanx is the one most frequently broken, the terminal phalanx most rarely.

The symptoms upon which the diagnosis is made in simple fractures are mobility and crepitation, since the displacements are usually masked by the swelling.

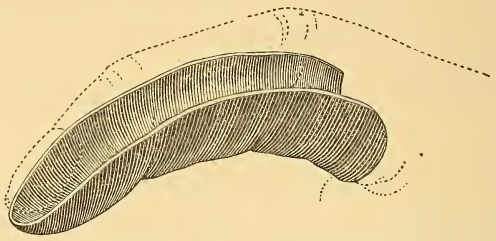
The progress of the case in simple fracture is towards prompt repair; in compound fractures the suppuration is apt to be profuse, and necrosis of splinters and even of one of the principal fragments is not uncommon.

A well-established rule of treatment in injuries of the hand is to save everything that can be saved, but it needs limitation in compound fractures of the fingers. While it is desirable to save the thumb or any part of it, even at the price of ankylosis of both the joints, the same value does not attach to the fingers, and a rigid deformed finger that has been saved with much difficulty, is often a source of so much inconvenience that the patient subsequently seeks relief in amputation. It is better that members so injured should be removed at first, for the attempt to save them cannot be made without incurring certain risks, prolonged suppuration, phlegmon of the forearm, tetanus, which, although somewhat remote, should not be lost sight of. This statement applies with especial force to the little finger, because of the communication of its

flexor sheath with the common one of the palm and wrist, a communication which does not exist in the case of the other three fingers. Although the treatment of inflammation of the hand does not fall within the scope of this work, I take the opportunity to testify to the value of antiseptic baths, and to urge free and early incisions with thorough drainage. It is my practice to place the hand for an hour or an hour and a half in a tepid bath containing two per cent. of carbolic acid and then to envelop it in thick layers of cotton bound on firmly with a roller bandage. The bath is repeated once or twice a day or once every two days according to circumstances.

In the treatment of simple fracture the usual indication to prevent displacement is habitually met by means of a moulded palmar splint made of pasteboard, felt, or gutta percha to which the finger, slightly flexed, is made fast (fig. 259). This answers very well for the terminal and

Fig. 259.



Hamilton's gutta percha splint for the finger.

middle phalanges but it does not support the proximal one sufficiently. Sometimes a straight splint is used, sometimes a plaster of Paris bandage, and sometimes extension is made by means of adhesive plaster as mentioned above in the treatment of fracture of the metacarpal bones.

The general impression seems to be that the displacement to be guarded against is an angular one with the angle directed backward and caused by the contraction of the flexor tendons. Mention has been made of an angular displacement in the opposite direction sometimes observed in the proximal phalanx, and it has been attributed to the pressure of the roller bandage which binds the finger to the splint; the phalanx rests upon the splint at its two ends while its centre is not only unsupported but is actually pressed out of line by the bandage. I have seen this displacement under circumstances where this cause could not be alleged, even in a case of recent fracture by indirect violence, and I attribute it to the action of the interosseous muscles. The persistence of this displacement constitutes a serious inconvenience, for it limits flexion of the metacarpophalangeal joint and creates a prominence upon the palmar aspect of the phalanx the skin covering which may become so sensitive that a firm grasp cannot be taken of any hard object.

A palmar splint does not prevent this displacement unless combined with permanent extension, and if used it must be carefully padded and frequently inspected. I prefer to close the hand upon some firm cylindrical body, a roller bandage for example, and fasten the fingers down with

strips of adhesive plaster applied longitudinally along the back of the hand, the fingers, and the front of the forearm, and additionally secured with a few turns of a bandage. The roll must be large enough to give ample support, and by passing the finger along the dorsum of the phalanx the occurrence of displacement can be recognized. It will be remembered that the tendon of each extensor muscle is attached to the base of the proximal phalanx by a short band which limits the action of the muscle to that phalanx, and that the extension of the middle and distal phalanges is accomplished by the interossei, which also flex the metacarpo-phalangeal joint and are relaxed when the fingers are closed. The tendency to overriding is thus effectively opposed by this position, and the displacement which most needs to be guarded against under the circumstances is the one also that is most readily detected, angular displacement with the angle directed backward.

Dr. Hamilton reports a case of union with rotatory displacement of the distal segment about its long axis, an unsightly and troublesome deformity that should be guarded against.

Support that may be sufficient in some cases can be readily obtained by binding the broken finger to the adjoining ones and supporting both or all three upon a common splint.

CHAPTER XXIV.

FRACTURES OF THE PELVIS.

These are among the rarest fractures, as may be seen by reference to the tables in Chapter I., averaging, perhaps, one in three thousand fractures of all kinds, although the percentage for obvious reasons is considerably higher in hospital practice.

The form, size, and connections of the bones which constitute the pelvis are such that their fracture can be caused, except at some of the more exposed and outlying points, only by extreme violence, a fact which taken in connection with the proximity of important viscera accounts for the recognized gravity of the injury. According to Agnew[1] the mortality was 36 in 94 cases admitted into the Pennsylvania Hospital, and 24 in 65 cases collected by Dr. Lyon.

Although the pelvis is composed of several different bones, it does not seem desirable to describe the fractures of each separately, especially since multiple fractures are common, and a single fracture may involve more than one bone. I shall therefore group in one section all fractures, single, double, or mutiple, which break the continuity of the ring of the pelvis, and then consider separately some fractures of the sacrum, coccyx, the wing of the ilium, and the ischium, which do not break the continuity of the ring.

1. Fractures of the Ring of the Pelvis.

The most frequent cause of this lesion is the passage of the wheel of a heavily laden wagon across the thigh and hypogastrium; among the others are falls upon the feet or the buttocks, the caving in of an embankment, and crushing between the buffers of railway cars or other heavy moving objects. The position and the number of the fractures vary with the degree of the violence and the portion of the ring upon which it is received. When it falls upon the symphysis and is directed backward the arch yields at its weakest point, and the line of fracture passes through the horizontal and descending branches of the pubis, sometimes on one side alone, sometimes on both sides. If the force then continues to act it presses the sides apart, and either breaks the sacrum vertically (by avulsion) or ruptures the ligaments of the sacro-iliac synchondrosis, or breaks the ilium into the synchondrosis or into the sacro-sciatic notch; and it does this also sometimes on one side alone, and sometimes on both. Voillemier,[2] who was the first to call attention to this combination with vertical fracture of the sacrum attributed it exclusively to falls upon the

[1] Loc. cit., vol. i. p. 921.

[2] Clinique Chirurgicale, 1862, p. 77.

ischium, and rejected the explanation offered of the only case reported before his, that of Richerand, who attributed it to a fall upon the foot.

When the violence is received upon the side of the pelvis, or the great trochanter, or even upon the foot, it may cause what Malgaigne described as double vertical fracture of the pelvis, or fracture of the acetabulum to a variable extent, and in one case a fall upon the foot caused dislocation of the entire os innominatum, separating it cleanly at the symphysis pubis and sacro-iliac joint and forcing it upward. In Malgaigne's double vertical fracture the anterior fracture occupies the same position as when the force has been received upon the symphysis, it crosses the pubis; the posterior one is usually entirely within the ilium and behind the acetabulum, but Malgaigne includes in this group Richerand's case, above alluded to, in which the posterior fracture occupied the sacrum, and there seems to be no good reason for separating this group from the main class, although the symptoms in it are made somewhat different by the greater mobility of the segment with which the femur articulates. In fracture of the acetabulum, which can be caused only by violence transmitted through the femur, the bone may be simply fissured, or the head of the femur may be driven entirely through into the cavity of the pelvis. In the slighter cases the continuity of the pelvic ring is not broken, but in the more extensive ones it is. In young people the lines of fracture may follow those of the developmental division of the bone into three.

The displacements are seldom great, but complications are numerous and serious. The most frequent is rupture of the urethra, usually in its membranous portion; among the others are rupture of the bladder and laceration of the iliac veins or the external iliac artery. Rupture of the bladder may be intra- or extra-peritoneal; in some cases it appears to have been caused by the direct pressure upon the bladder of the object which caused the fracture, in others by a splinter or the displaced fragment. The other two lesions mentioned are due to the displacements. The separation of the pubes tears the urethra across at or near the triangular ligament, and the projecting edge of the posterior line of fracture lacerates one of the iliac veins, or the edge of the anterior one tears the external iliac vein or artery.

In a case referred to briefly by Legros Clarke[1] there were several fractures, and separation of the sacro-iliac synchondrosis on each side and of the pubic symphysis to the extent of four inches. The rectum was ruptured and feces were extravasated into the pelvis; the bladder was ruptured and the urethra torn completely from the prostate gland.

The varieties and the symptoms which vary notably with them require separate mention.

Separation of the symphysis pubis, which, like fracture or diastasis of the costal cartilages, falls directly within the classification, may be produced by external violence acting directly upon the pubic arch or through forced abduction of the thighs, or by the descent of the fœtus through the superior strait in parturition. Malgaigne collected seventeen cases of the latter, most of them occurring in primiparæ, and most by the un-

[1] Diagnosis of Visceral Lesions, p. 339.

aided action of the patient's muscles; in a few cases the forceps were used. Usually the separation takes place with a distinct cracking sound, and the gap can be felt with the finger, and in one or two cases the fracture has been made compound by simultaneous laceration of the soft parts. The gap is the chief diagnostic symptom. The scanty information possessed upon the subject indicates that, in the traumatic cases at least, the separation takes place not between the cartilages, but between the cartilage and the bone.

The traumatic cases are less numerous and more varied in their details, although in a large proportion of them the force seems to have been exerted through the adductor muscles of the thighs. In two cases quoted by Malgaigne, in a third reported by Weber,[1] and in a fourth by Earle,[2] the patient was on horseback and received the injury either by being thrown forward upon the withers, or first to one side and then to the other, or by the muscular effort made to keep his seat. In one of Malgaigne's cases the results were an immediate hernia, rupture of the perineum with a separation at the symphysis that would admit the hand, and pain at each sacro-iliac synchondrosis. This patient recovered in three and a half months, the treatment consisting of a bandage drawn tightly about the pelvis, with the limbs resting upon a double inclined plane.

In Earle's case there was collapse, severe pain, flattening of the pubes, and free bleeding from the anus. An incision in the perineum gave exit to blood and urine. The patient survived for only forty hours, and the autopsy showed a separation of three inches at the symphysis, the left sacro-iliac synchondrosis gaping one inch, and the prostate torn completely away from the bladder and hanging down in a cavity filled with clot. The patient was between 60 and 70 years of age.

In another singular case quoted by Malgaigne the patient, a lad 18 years old, was learning to be a dancer. His teacher made him lie upon his back on the floor with his thighs flexed, and then standing upon him with one foot on each knee, sought to force the thighs outward. It caused the bones to separate at the symphysis to the extent of half a finger-breadth.

In a case reported in the *Lancet*, 1865, vol. ii. p. 348, a man 44 years old was run over by a heavy dray, the wheel crossing the upper portion of the thigh and lower part of the abdomen, and died in three days. There was separation at the symphysis to the extent of three inches which could be closed by pressure on the sides of the pelvis; the adductor longus and gracilis were torn at their origin; there was a fracture of the pubis on each side at the pectineal eminence, running into the acetabulum, and the sacro-iliac synchondrosis gaped widely. The urethra was lacerated "a little anterior to the membranous portion."

In the case reported by Lente,[3] a lad 18 years old was crushed between two cars, and the right pubis displaced backward half an inch. The bladder was ruptured and the patient died in two days.

In Sir Astley Cooper's[4] case a quantity of gravel fell upon the back of

[1] Gaz. Méd. de Strasburg, 1872.
[2] Med. Chir. Trans., vol. xix., 1835, p. 257.
[3] New York Journal of Medicine, May, 1850, p. 286.
[4] Loc. cit., p. 144.

the patient, who was 22 years old, as he was stooping, and caused separation at the symphysis to the extent of about two finger-breadths. The patient experienced violent pain in the region of the bladder and said that the urine he first voided was bloody. The catheter was introduced and the urine found to be clear. He recovered in three months, with some slight separation remaining and lack of symmetry in the position of the spinous processes of the ilia.

In a case reported by Gay,[1] a young man fell while drunk from a second-story window and broke his right thigh. By pressing back upon the ilium the symphysis pubis could be separated half an inch. There was complete retention, and hemorrhage from the urethra. The catheter brought bloody urine. He was discharged cured in seventy-four days.

Separation in Front and Behind.—In one of Mr. Earle's cases (loc. cit., p. 261, Case 5), there was complete separation of the left os innominatum, both in front and behind; the bone was forced up to a considerable extent, and the common iliac vein torn across. The patient was a young man, and received the injury by jumping from a third story; he landed upon the left foot, causing also a compound comminuted fracture of the calcaneum and astragalus.

Similar cases were collected by Malgaigne, and two have been recently published by Salleron.[2] The injury has been caused by a fall upon one foot or upon the side of the pelvis, or by the pressure of a heavy weight upon the front of the pelvis. The characteristic symptom is the elevation of the corresponding half of the pelvis with absence of the crepitation which is usually present in double vertical fracture. The thigh is rotated outward and the limb apparently shortened, and the injury has been mistaken for fracture of the neck of the femur. The error could probably be avoided by careful measuring and by localizing the painful points. Salleron was able to reduce the dislocation in his cases, and both recovered, but as a rule the prognosis is extremely grave.

Separation of the Sacro-iliac Synchondrosis.—Simple separation of this joint is very rare. Malgaigne (loc. cit., vol. ii. p. 777) quotes one case of it, and four others in which there was in addition fracture of the ilium. In the one simple case, reported by Philippe, 1768, the injury was caused by the fall of a sack of grain weighing 350 pounds upon the patient, who was standing with his back bent. He was able to continue his work, feeling no inconvenience except a slight local numbness. On the third day the pain returned, paraplegia followed, and he died on the twentieth day.

In a case diagnosed as such by Salleron (loc. cit., 3d Case) the patient, a man 28 years old, was thrown forward upon his face by the fall upon his back of a mass of limestone from a height of three or four yards. The diagnosis was made upon the displacement of the posterior spine of the ilium, the pain, and the absence of signs of fracture at any point. The patient recovered.

The lesion is said also to have been produced during labor.

Separation of all three Joints.—A few cases have been reported as

[1] Boston Med. and Surg. Journal, 1876, April 13, p. 415.
[2] Archives Gén. de Méd., 1871, vol. ii. p. 34, Cases 1 and 2.

such, but in most there has been also fracture at one or more points, and the separation of one or both of the sacro-iliac synchondroses has been only the gaping of the joint due to the lateral separation of the two halves of the pelvis and not a real displacement. Malgaigne quotes briefly five cases in four of which there were associated fractures of the pelvic bones. Dolbeau,[1] Dubrueil,[2] and Pollock[3] have since reported others. Dubrueil's is the only one in which there seems to have been actual displacement at all three points, and even in it there was also a slight fracture. The patient was run over by a wagon. There was separation of two and a half inches at the symphysis pubis and gaping of both sacro-iliac synchondroses. The sacrum was displaced forward, projecting at the level of the superior strait two centimetres in front of the right ilium and one and a half in front of the left. There was a fracture at the junction of the right ischium and pubis, and partial fracture of the body of the right pubis.

In each case the injury was caused by extreme violence acting directly upon the pelvis, the passage of a heavy wagon, the fall of a heavy object. All terminated fatally.

Fracture of the pubic portion of the pelvic ring, which is the most common of all, passes usually through the horizontal ramus just in front of the ilio-pectineal eminence and through the descending ramus near its junction with the ischium. The fracture may be oblique or transverse, may be double (of one or both pubic bones), or may be associated with separation of the symphysis or with other fractures of the lateral or posterior portions of the pelvis. As has been already mentioned, rupture of the ligaments of one or both sacro-iliac synchondroses with gaping of the joint is a frequent accompaniment when the action of the fracturing force is momentarily prolonged.

The displacement is sometimes so marked that it can be easily recognized by the eye; in other cases the diagnosis can only be made after palpation of the outline of the bone which is quite accessible to the touch.

Interference with the voiding of the urine, either by rupture of the urethra or by pressure upon it, is a very frequent complication; Rose,[4] indeed found it absent in only 1 of 10 certain cases. In a case which came under my care at the Presbyterian Hospital, in which both rami of the left pubis had been broken, with slight displacement upward of the inner fragment, by the caving in of an embankment, there was no injury to the bladder or urethra; the patient recovered.

Injury to the urethra takes place usually in the membranous portion, but occasionally behind or in front of it. The bladder, too, has been sometimes torn by a fragment or ruptured by pressure.

The following are the more noteworthy complications and varieties that have been recorded. A man, 20 years old, was run over by a railway train and received a fracture of the crest of the right ilium, the ramus of the left pubis, and of the "right pubis close to its junction with the iliac portion of the bone, the sharp end of this fracture had entirely divided the external iliac artery."[5] A man, 43 years old,

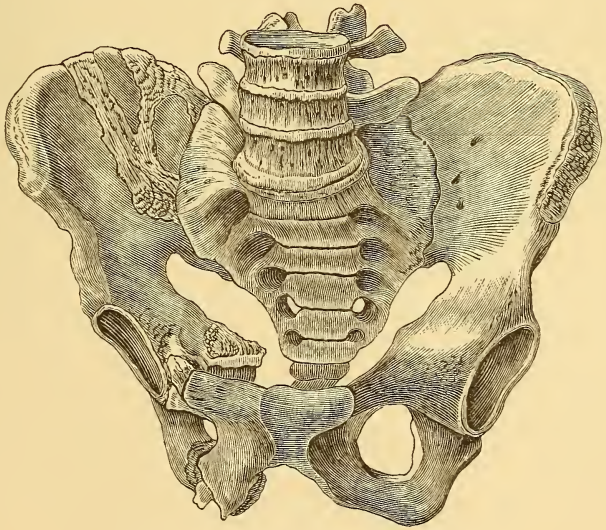
[1] Gazette des Hôpitaux, 1868, p. 194.
[2] Id., 1871, p. 413.
[3] The Lancet, 1872, vol. ii. p. 409.
[4] Charitéannalen, vol. xiii. part 2.
[5] Lancet, 1878, vol. i. p. 347, Case 2.

was run over by a wagon, was brought to the hospital insensible, and died in three hours. There was fracture of the "ramus and body of the pubis on both sides, and separation of the sacrum from the left os innominatum. Fracture of the left ilium, the fracture extending across the pectineal line and causing laceration of the left external iliac vein."[1] A man was crushed under a heavy iron door and received a fracture of the body of the pubis on each side, traversing the ascending rami of the ischia. "The pubes were greatly depressed and the urethra was torn across through the muscular part just beyond Camper's ligament which remained entire."[2]

The following are quoted from Malgaigne. Nivet presented to the Société Anatomique a specimen of double fracture of the ramus of the pubis; the detached fragment had been displaced in front of the body of the bone, and had torn through the skin in the fold of the thigh. Maret saw a case of fracture of the body of the pubis in which the fragment, displaced forward and inward, prevented the introduction of a catheter. He made an incision on the inner surface of the labium majus and withdrew the fragment which consisted of almost the entire body of the pubis. The patient recovered and bore children safely afterwards. In a case treated by Nélaton, a fragment perforated the bladder and vagina and was removed through the latter.

Fracture of the lateral portion of the ring occurs in two principal forms, one in connection with fracture of the pubic portion, the other a

Fig. 260.



Double vertical fracture of the pelvis; united.

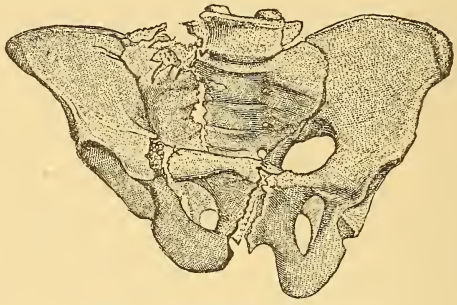
fracture radiating from the cavity of the acetabulum. The former is the one to which attention was first called by Malgaigne under the title of

[1] Idem, Case 3.

[2] Earle in Med. Chir. Trans., vol. xix., Case 4.

double vertical fracture of the pelvis, and a variety of which has been described at much length by Voillemier (vide supra) as *vertical fracture of the sacrum*. The posterior line of fracture lies either in the ilium entirely behind the acetabulum, or in the sacrum, or partly in the ilium or sacrum and partly in the sacro-iliac synchondrosis, and sometimes the sacrum is crushed rather than fractured. The most prominent symptoms in these cases are in the position of the leg and in the extent to which it can be moved. The femur is attached to the portion of bone which is intermediate between the two lines of fracture, and as this piece is usually displaced upward, there is apparent shortening of the limb. At

Fig. 261.



Double vertical fracture of the pelvis.

the same time the piece is commonly rotated about an antero-posterior axis so that the upper part of the pelvis is broadened and the lower part narrowed. The inability to move the limb is due in part to the lack of a solid support and the fear of pain, and in part perhaps to laceration of the muscles of the iliac fossa. The fracture is produced commonly by violence acting directly upon the ilium, as in the passage across it of a heavy body or in a fall. The prognosis is unfavorable because of the probability of associated injuries, but if these do not exist, there is little in the fracture itself to endanger life. It may result in lameness or in a permanent change in the shape of the pelvis, which, as in the following case quoted by Malgaigne from Papavoine, may have the most serious consequences. A woman, 34 years old, was kicked by a horse upon the right side of the pelvis and received a double vertical fracture, the anterior one in the usual place, the posterior one on the ilium a little in front of the sacro-iliac spmphysis. She recovered in four months, but the fragment had united in such a manner that the transverse diameter of the superior strait measured $5\frac{1}{2}$ inches, and that of the inferior strait only $2\frac{2}{3}$ inches. Two years afterwards she returned to the hospital to be confined. She had previously had five simple labors, but this time she was delivered only on the fourth day and with the aid of forceps. The necessary tractions were so violent that she received, in addition to other very grave injuries, a fracture of the right ischium, and died two days afterwards.

In a case reported by Panas[1] there was a double fracture on each

[1] Gazette des Hôpitaux, 1868, p. 180.

side. The patient was a man 35 years old, who was brought to the hospital after having been run over by a heavy wagon, and died in thirty-six hours. There was no deformity of the pelvis, but crepitation could be felt. On the right side the anterior fracture crossed both branches of the pubis at the inner side of the foramen ovale, and the posterior fracture began two centimetres from the posterior superior spine of the ilium and passed into the lower part of the sacro-iliac synchondrosis. On the left side the anterior fracture was at the outer border of the foramen, and the posterior one involved the base of the sacrum at its upper part and passed thence into the sacro-sciatic notch at the bottom of the synchondrosis. The bladder was ruptured posteriorly.

The second form of lateral fracture of the pelvis, radiating fracture of the acetabulum, is produced by violence acting through the femur, and is quite rare, although Dupuytren says he has met with it a number of times. The fracture may be no more than a simple fissure, or the head of the femur may be driven entirely through into the pelvis. Dr. Agnew refers to a preparation in the collection of Dr. Neill in which the lines of fracture follow those of the embryonal division of the bone; the union is complete, and there is very little callus on the articular surface.

Mr. Travers[1] expressed the opinion in a paper read before the Medico-Chirurgical Society that the symptoms of fissured fracture were acute pain provoked by pressure upon the spine of the pubis and inability of the patient to stand, but as the diagnosis in the two supposed cases upon which his paper was based was not verified by autopsy, his interpretation of the symptoms is open to question.

The symptoms of the more severe variety, that in which the head of the femur is driven more or less completely through into the pelvis, have varied considerably in the different cases, and the diagnosis has not always been made during life. Sometimes there is outward rotation, fixation, and extreme pain on motion; in other cases the movements of the limb are quite free and painless within certain limits. Shortening is slight or absent, the trochanter is sunk, and there is absence of crepitus. Interesting fatal cases have been reported by Drs. Neill,[2] Sands,[3] and Lawson.[4]

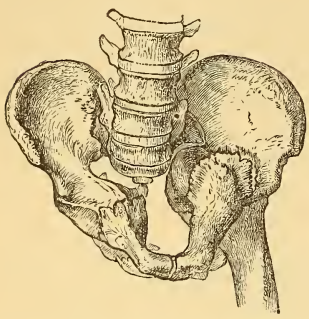
A remarkable case, which will serve to illustrate the possibilities of repair, is one reported by Mr. Moore.[5] A man received a severe injury of the hip, thought to be fracture of the neck of the femur; he recovered and was able to walk with only a slight limp. At the autopsy several years afterwards the injury was found to have been a fracture of the pubis, ilium, and acetabulum, which allowed the head of the femur to pass through into the pelvis, the trochanter resting against the acetabulum (fig. 262).

Similar cases are those reported by Lendrick and Morel-Lavallée.

[1] Lancet, 1854, i. p. 211, and Holmes's Syst. of Surg.
[2] Trans. Coll. of Physicians Philada., vol. ii. p. 267.
[3] N. Y. Med. Record, 1877, p. 93.
[4] Lancet, 1878, i. p. 382.
[5] Med.-Chir. Trans., vol. xxxiv. p. 107.

Lendrick's[1] case was that of a man known as the Wandering Piper, who received a severe injury thought to be a fracture of the neck of the femur, and died several years afterwards of phthisis, having been able to make much use of the limb in the mean time. The head of the femur was found projecting into the pelvis through a rent in the acetabulum. A bony case had been formed for it, but a portion about the size of a shilling was uncovered except by ligament. The pubis had also been broken and had united with much overlapping.

Fig. 262.



Head of the femur driven through the acetabulum.

In Morel-Lavallée's[2] case the injury was thought to be a fracture of the neck of the femur. The autopsy, made long afterwards, showed multiple fracture of the pelvis united with displacement; the head of the femur penetrated to the distance of more than an inch into the pelvis and raised the obturator nerve, the stretching of which appeared to have been the cause of the sharp pains which had been attributed during life to coxalgia.

Vertical fractures of the sacrum are not known except in connection with fractures of the pelvic ring at other points, as already mentioned. A few cases of very extensive injury have been recorded, extensive crushing and multiple fractures. All proved fatal.

The *course and prognosis* in all these cases depend mainly upon the lesions associated with the fracture. The only additional point which requires mention is one referred to by Legros Clark, the tendency to suppuration in the loose connective tissue between the pubes and the bladder, especially after fracture of the pubis or separation of the epiphysis. The uncomplicated and simpler forms of fracture tend to easy repair, and even fractures that are very extensive are by no means necessarily fatal, as is proved by many specimens.

Diagnosis.—The diagnosis is usually easy but may be very obscure if the fracture is limited and without much displacement. The outline of the pubis should be carefully followed with the finger to detect irregularity or localized pain, and pressure should be made backward alternately with either hand upon the anterior portion of each ilium in the search for abnormal mobility and crepitus. In vertical fracture of the sacrum or in separation of the sacro-iliac synchrondrosis displacement will change the position of the posterior spine of the ilium. In double vertical fracture the intermediate portion, which bears the anterior superior spine, is usually displaced upward, and the displacement is easy of recognition and can be diminished or perhaps reduced by traction upon the leg. Fissured fracture of the acetabulum would probably pass unrecognized, or, at the most, be only suspected from the history of a fall upon the trochanter, knee, or foot with pain in the joint

[1] Lond. Med. Gazette, vol. xxiii., 1838-39, p. 828.
[2] Quoted by Malgaigne, loc. cit., vol. ii. p. 881.

and the absence of dislocation or of fracture of the femur. Fracture of the acetabulum with displacement of the head of the femur into the cavity of the pelvis will probably be recognizable by palpation of the iliac fossa through the anterior abdominal wall or by digital or manual exploration through the rectum.

Treatment.—Reduction has sometimes been made by lateral pressure or by traction upon the thigh, especially after separation of the epiphysis or double vertical fracture, and the effort when practicable should of course be made. The means of retention are limited mainly to a bandage or girdle drawn snugly about the pelvis and to rest in the dorsal recumbent position. Continuous extension, as in the treatment of fracture of the thigh, may be useful in double vertical fracture or fracture of the acetabulum to prevent displacement upward.

Treatment of the complications belongs more properly to the subject of general surgery, but the frequency of laceration of the urethra and the advantages of its early recognition and treatment are so great that it deserves mention. On the first indication of probable injury to the urethra the catheter should be introduced, and if its passage is prevented or even rendered difficult by injury to the urethra, an incision should be made through the perineum to the injured part, cutting upon the end of the catheter as a guide. It is entirely unnecessary to prolong the incision to the neck of the bladder, as recommended by some, in cases in which the injury is limited to the urethra. If the bladder itself has been ruptured cystotomy may be required, but under other circumstances it is necessary only to afford a free outlet to the urine at the lacerated part of the urethra. The subsequent treatment of the urethra is the same as after external perineal urethrotomy for stricture; a full-sized instrument must be passed at intervals of about a week.

2. Transverse Fracture of the Sacrum.

This rare injury is produced by blows or falls upon the corresponding region, and appears in all cases to have occupied the lower half of the bone and to have been produced by the forcible bending inward of its apex. Its direction is practically transverse. Malgaigne has reported one case of oblique fracture; in it the violence was received upon the side of the bone, and there were also two incomplete transverse fractures.

The usual displacement is an angular one, the coccyx and lower fragment being drawn forward so that the apex of the angle is directed backward at the seat of fracture. The displacement is due in part to the fracturing force and in part to the action of the attached muscles. In a case that came under my observation at Bellevue Hospital there was extensive sloughing over the sacrum and denudation of the bone, apparently due to the direct violence that caused the fracture. The same complication is mentioned in two of the five cases collected by Malgaigne, both terminating fatally.

The symptoms are pain at the seat of fracture, both spontaneous and provoked by pressure or movements of the trunk, or by the act of defecation, or perhaps by the act of coughing; the displacement if present;

and abnormal mobility and crepitation recognized by grasping the lower fragment between the thumb and a finger introduced into the rectum.

Agnew[1] says "there will probably be present paralysis of the bladder and rectum, both of these organs receiving nerves from the sacral plexus," and Lossen[2] says that when there is complete displacement of the fragment paralysis of the lower extremities, bladder, and rectum is never absent, but neither author quotes any cases in support of the statement. In the one case that has come under my own observation, there was almost complete paralysis of the lower limbs, bladder, and rectum, which now, nine months after the accident, has been recovered from in great part.

Burlingham[3] reported a case which he thought to be a comminuted fracture of the outer surface of the bone not involving its entire thickness, with much laceration of the soft parts and flow of urine through the wound. The patient made an incomplete recovery, and the nature and extent of the injury remain obscure.

In Bermond's case, quoted by Malgaigne, the fracture was near the coccyx, and the lower fragment was displaced so far forward that the finger could not be passed into the rectum until after a female catheter had been introduced as a guide. The pain was extreme, was relieved by the reduction of the displacement, and returned as soon as the finger was withdrawn.

Treatment.—Unless there is marked displacement, no treatment is required beyond the use of pads or rings to relieve the lower fragment from pressure. In some cases the surgeons have sought to diminish the pressure by flexing the thighs and supporting them upon pillows piled up under the knees.

In two cases the surgeon tried to make direct pressure upon the lower fragment by dressings introduced into the rectum. Judes, quoted by Malgaigne, used a cylinder of wood five inches long and one inch in diameter with graduated compresses outside and a T-bandage to support the whole. Bermond filled the rectum with a bag of lint, which soothed the patient's pain but had to be removed on the following day to allow the bowels to be emptied. He then used a shirted canula through which the gas and feces could be passed at will while the rectum was kept distended by the tampon. It was removed temporarily on the seventh day, and finally on the nineteenth, when abnormal mobility could no longer be detected.

3. Fractures of the Coccyx.

There is but little definite knowledge concerning this lesion. The first mention of it appears to be that of Cloquet in the statement that when in old people union has taken place between the different portions of the coccyx, and between it and the sacrum, the coccyx might be broken by a fall upon the buttocks or, as in a case which he had seen, by a kick upon the same part. He refers also to another case in which caries of the

[1] Loc. cit., p. 922. [2] Deutsche Chirurgie, Lief. 65, p. 7.
[3] Am. Journal Med. Sciences, Apl. 1868.

coccyx followed its fracture, but, as Malgaigne says, it does not appear that Cloquet verified the fracture. Within a few years several cases have been published, and it is furthermore possible that some of the cases described as dislocations of the coccyx may have been fractures. None of the cases of fracture mentioned have been described with any details, and there is, therefore, nothing to be said except that the diagnosis must be made as after fracture of the sacrum, and that probably no treatment would be required except to reduce displacement. The few recorded cases of dislocation have been marked by extreme pain relieved promptly by reduction: and in only one was there any tendency to reproduction of the displacement.

Severe persistent pain in the region of the coccyx, *coccygodynia*, sometimes follows a blow, and it is possible that in some of the cases the bone may have been broken. Dr. Mursick[1] removed a portion of the coccyx in two such cases, and says the same practice has been followed by others with good results. Dr. Agnew's suggestion that such cases should be treated first in accordance with the method introduced by Simpson, subcutaneous division of the attachments of the coccyx to the underlying soft parts, will commend itself to all.

4. Fracture of the Ilium.

Fractures of the expanded upper portion of the ilium are comparatively frequent and vary widely in their position and extent; the more extensive ones pass transversely or obliquely from before backward at some distance below the crest and are associated sometimes with vertical lines which divide the upper fragment into two or more portions. Malgaigne says that when the fracture lies near the crest it begins commonly at a triangular prominence on the crest near its middle, and runs thence backward or forward, or in both directions, following a curved line the concavity of which is directed upward. The fracture may be limited to a small portion of the rim of the bone, as the anterior superior spinous process or the outer lip of the crest. In a unique case observed by Dr. Hamilton, the posterior superior spinous process was broken off by a fall upon the back; and Riedinger and Linhart[2] have shown experimentally that the anterior inferior spinous process can be torn off by putting the Y-ligament of the hip-joint upon the stretch. In a case reported in the Bulletins de la Société Anatomique, 1867, p. 283, the anterior superior and inferior spinous processes were broken off while still in the condition of epiphyses by the passage of a wagon. The patient was fifteen years old.

The *cause* has heretofore been thought to be direct violence exclusively, but Dr. Hamilton has reported a case of fracture of the anterior superior spinous process by muscular action, and the same agency appears not improbable in other fractures of the same part. Riedinger asserts the same cause in many fractures of the crest, but brings no clinical or experimental facts to demonstrate the correctness of the

[1] Am. Journal Med. Sc., Jan. 1876, p. 122.
[2] Langenbeck's Archiv, vol. xx. p. 451.

opinion. Considering the strength of the muscles attached to the ilium and the occasional correspondence of the fragments to the insertions of the muscles the theory does not seem unreasonable.

Symptoms.—The usual signs of pain and swelling are increased by the associated bruising of the overlying soft parts, abnormal mobility and crepitation can be felt on manipulation at times, but their manifestation depends upon the position of the fragment, the posture of the patient, and the contraction or relaxation of the muscles. In a case under my care where a large fragment composed of the anterior half of the crest and the adjoining bone had been broken off by a fall, mobility and crepitation would at times disappear entirely, apparently in consequence of slight changes in the position of the fragment. In other cases extension of the thigh prevented mobility, apparently by making the iliacus internus muscle tense. In seeking for mobility and crepitation the abdominal muscles should be relaxed by bending the body forward and to one side, and the thighs should be flexed on the pelvis.

The patient is usually unable to walk, because of pain or of the sense of a lack of support. The displacement in the case of fracture of the anterior superior spinous process is downward in the direction of the sartorius muscle, and in one recorded case of fracture of the crest the fragment was drawn upward nearly to the ribs.

The *course* is usually a simple one, and the patients are sometimes able to leave their beds in two or three weeks. In some very exceptional cases where the violence has been extreme fatal injury has been done to the viscera, such as perforation of the intestines by a splinter or laceration of the iliac veins; and suppuration has sometimes taken place, probably in consequence of comminution and necrosis of a splinter, although in a case of fracture near the crest which came under my care a few weeks after the accident, and after the abscess had opened externally I was unable to find any splinter on exploration of the seat of fracture with the finger. In Duverney's case, quoted by Malgaigne, the patient died on the fortieth day in consequence of profuse suppuration which filled the entire pelvis.

The *treatment* is simple, rest in bed in the position which gives most ease and is most favorable to the relaxation of the muscles which would be likely to cause displacement. The attempts that have been made in the few recorded cases of fracture of the spinous processes to keep them in place by pressure with pads and bandages have been entirely unsuccessful. A circular body bandage is thought by Malgaigne to be harmful rather than advantageous because it favors displacement of the fragment inward. Hot fomentations or poultices may be required to combat inflammation at first. In consideration of what appears to be an exceptional tendency to necrosis on the part of the fragments of the bone it will be proper in compound fractures to remove all detached or loose fragments.

5. Fracture of the Ischium.

This is one of the rarest of the fractures of the pelvis. Malgaigne collected only six cases, and the list has not been since increased by any reported in detail. In some of the cases almost the entire ischium was

broken off, in others only the tuberosity. In three of Malgaigne's cases the cause was a fall upon the buttocks, the fourth was a gunshot fracture, the fifth was caused by an explosion, and the sixth was the one mentioned above of a woman who had recovered from a double vertical fracture of the pelvic ring with a displacement that narrowed the inferior strait so much that two years afterwards delivery could be effected only with the aid of forceps, and the ischium was broken in the effort. In two of the cases the fracture was comminuted, and in one of them also compound, in the other the scrotum was lacerated and the urethra torn, presumably by violence received at the same time upon the perineum and not by displacement of the bone. In a case described by Sir Astley Cooper[1] and quoted by Hamilton as a fracture of the ischium with rupture of the urethra caused by the passage of the wheel of a cart, the fracture was probably of the pelvic ring and not of the ischium alone. In the simple cases there was little or no displacement; in the gunshot fracture the fragment was displaced downward more than two inches by the contraction of the hamstring muscles. The displacement persisted, but does not appear to have interfered materially with the movements of the limb. All except the sixth recovered.

Mobility and crepitation can be recognized by manipulation of the bone, preferably with the finger in the rectum or vagina. The severity of the pain depends upon the violence and the associated injuries and makes it difficult for the patient to walk.

No treatment is required except rest in bed with pillows or air-cushions so arranged as to prevent pressure upon the broken bone. If the patient lies upon the side the knees may be kept flexed to relax the muscles which are attached to the ischium.

6. Fracture of the Pubis.

In almost all cases of its fracture the pubis is so broken that the continuity of the pelvic ring is destroyed; the cases in which only one ramus has been broken, or in which a lateral fragment has been broken off are extremely rare, and consequently there is but little to be added to what has been already said in the first portion of this chapter. The only cases of this limited fracture of which I have any knowledge are one reported by Nivet, and one by Cappelletti. In Nivet's[2] case, the account of which is not quite clear, there appears to have been a double fracture of the descending ramus, the intermediate piece was displaced forward and had torn the skin of the groin. In Cappelletti's[3] case a man jumped from a carriage, alighting upon his feet with one limb widely abducted. Six months afterwards there was still some swelling at the anterior superior part of the right thigh, and a fragment of bone about two and a half inches long and as large as the finger could be felt there. Cappelletti was convinced that this fragment was a portion of the descending branch of the pubis and the ascending branch of the ischium detached

[1] Fracts. and Disloc., Am. ed., p. 140, Case 74.
[2] Bull. de la Société Anatomique, 1837, p. 194.
[3] Ranking's Abstract, vol. viii., 1848, p. 91.

by muscular action. The pelvis appeared to be defective anteriorly at the point corresponding to the supposed original seat of the fragment, there was acute pain on pressure at the swelling and at the tuberosity of the ischium, the patient walked limping and with pain, and the pain was increased by abduction of the limb.

7. Fracture of the Rim of the Acetabulum.

This is a lesion which sometimes accompanies partial or complete dislocation of the femur upon the pelvis. Malgaigne says the first recorded case was observed by Sir Astley Cooper in 1805, but does not give the reference. In Cooper's *Dislocations and Fractures* (Am. edition, p. 137) an account is given of a case admitted into Guy's Hospital in 1791, under the care of a surgeon who is not named, in which the character of the injury was made known by post-mortem examination. The posterior part of the acetabulum was broken off, and the head of the thigh bone had slipped from its socket. There were other fractures of the pelvis on both sides, laceration of the kidney, and abundant hemorrhage into the cavity of the abdomen. A sufficient number of cases have since been observed and reported to make the history of the lesion complete.

The upper and posterior portion of the rim is the part most frequently broken, and the accompanying dislocation is commonly backward. In one of M'Tyer's cases[1] there were two fragments, and in Maisonneuve's case three, but in this latter the fracture was much more extensive. In another case (M'Tyer) the fracture had united with but slight displacement, and the ligamentum teres was untorn.

The symptoms, when the case first comes under observation, are those of simple dislocation backward, and the complication of fracture is recognizable only by slight crepitation felt on manipulation or during reduction and by the easy recurrence of the dislocation after reduction. Sometimes the head of the bone slips out of its socket again as soon as the traction ceases, in other cases only after the lapse of a few hours or on movement of the limb or body. In Maisonneuve's case[2] the dislocation was incomplete backward, movement of the limb caused distinct crepitation, reduction was made by slight traction downward, and the displacement recurred promptly when the limb was adducted, but not when it was kept abducted.

Malgaigne calls attention to the necessity of making sure of the existence of a dislocation, and of not depending for the diagnosis solely upon crepitation and easy recurrence of the displacement, signs which may accompany fracture of the neck of the femur. The prominent distinction between dislocation backward and fracture of the neck of the femur is in the position of the limb, which is flexed upon the pelvis and rotated inward in the former, and usually straight and rotated outward in the latter, but this alone should not be depended upon, the position of the head of the bone should be made out.

[1] Glasgow Med. Journal, 1830.
[2] Revue Médico Chirug., vol. xvi. p. 48. Quoted by Malgaigne.

The treatment should be directed to the prevention of a recurrence of the dislocation after its reduction. Continuous extension gave a good result in one case; and in Maisonneuve's case in which the tendency to dislocation was manifested only when the limb was adducted the surgeon kept the limb partly flexed and widely abducted. The patient died on the twenty-seventh day, and the fragment was found to have re-united.

CHAPTER XXV.

FRACTURES OF THE FEMUR.

The tables in Chapter I. show the great preponderance in number of fractures of the upper extremity over those of the lower extremity in the combined records of hospital and "out-patient" or Dispensary practice. The records of the London Hospital for twenty-six years show in a total of 51,938 fractures 27,119 of the upper extremity (including the clavicle), and 13,750 of the lower extremity. Of these 3243, six per cent. of the whole, were of the femur. The Berlin and Halle records, quoted by Gurlt (Chapter I. Table I.) show in totals of 232 and 97 fractures of the thigh, 76 and 21 of the neck of the bone respectively. The records of Bellevue Hospital for nine years, collated by Dr. F. E. Hyde,[1] contained 302 cases of fracture of the thigh, in which the position of the fracture was stated, divided as follows: neck 61, upper third (exclusive of neck) 34, middle third 169, lower third 31, of which 7 were of the condyles. Of 236 fractures of the thigh recorded by Dr. Hamilton, 84 were of the neck, 30 of the upper third, 86 of the middle third, and 36 of the lower third.

Malgaigne's analysis of 308 fractures (104 of the neck, 207 of the shaft) according to age and sex is as follows:—

Fractures of the Shaft.

Age.	Male.	Female.	
2 to 20 years	35	12	
20 " 40 "	47	6	
40 " 60 "	43	15	
60 " 80 "	20	29	
	145	62	= 207

Fractures of the Upper Extremity.

Age.	Male.	Female.	
4 to 50 years	9	5	
50 " 60 "	9	10	
above 60 "	30	41	
	48	56	= 104

1. Fractures at the Upper End of the Femur.

In this class are included fractures of the neck of the femur within and without the capsule, fractures of the trochanter and separation of its epiphysis, and fractures through the trochanter.

[1] N. Y. Medical Record, 1875.

Dupuytren[1] says that a rather common effect of falls upon the feet or the trochanter is the crushing of the head of the femur, the neck being left entirely uninjured. The injury passes for a simple contusion and the patients recover without deformity. He quotes no cases in support of this remarkable statement. The injury, so far as I know, is not mentioned by any other writer, and there is no report of any case, and no specimen in any museum.

A. Fractures of the Neck of the Femur.—This is essentially a lesion of advanced middle life and old age, and, as the second table given above shows, is more common in old women than in old men. It is often produced, too, by slight causes, such as a misstep, a stumble, a fall upon the knee or hip, and these two facts taken together indicate senile change in the bone as a markedly predisposing cause. Examination of the thigh bones of old people, those that have been broken and those that have not, bears out this indication, for it shows all the parts of the bone much rarefied, with thinning of the cortical shell and enlargement of the meshes of the spongy tissue. A former theory which attributed the frequency of fracture to an increase in the proportion of the earthy matter of the bone in old age has been shown to be unfounded in fact; the proportion of earthy matter in the bone tissue itself is not diminished, the change is in the amount of the bone as compared with the intermediate spaces occupied by the bloodvessels and fat, the compact tissue grows spongy, the spongy tissue grows spongier or more like the medullary canal. In one case I found the specific gravity of the femur only 1078; the bone was that of a feeble, badly-nourished man 40 years old who died three months after having broken the neck of the femur at the base by a fall to the ground while walking. This change is more marked in old women than in old men.

Another reason for the greater frequency of these fractures in the old has been sought in a change alleged to take place in the angle at which the neck joins the shaft. It was asserted that as the individual grows older this angle approaches a right angle, a position that would favor fracture, but examination has proved this not to be the case. Rodet[2] found the average angle in the child and adult 131°, and in the old 128°, a difference too small to deserve attention, especially since the limits between which the angle ranges normally are wide, 121° and 144° according to the same author.

Other points in the connection between the neck and the shaft require mention because of their influence in the production of the fracture and in the character of the displacement. The antero-posterior diameter of the neck is much smaller than that of the shaft, and the two are so joined that a large part of the great trochanter lies behind the posterior wall of the neck, and, as shown by Prof. Bigelow,[3] it is traversed in part by a prolongation of the posterior wall of the neck (fig. 263). This prolongation which Bigelow calls the true neck constitutes a vertical septum, "a

[1] Leçons Orales, vol. ii. p. 111.
[2] Thèse de Paris, 1844, quoted by Tillaux and others.
[3] The Hip, p. 121.

thin dense plate of bone continuous with the back of the neck, and reinforcing it, plunging beneath the inter-trochanteric ridge in an endeavor to reach the opposite and outer side of the shaft. At its lower extremity it curves a little forward so as to take its origin, when on a level with the lesser trochanter, from the centre instead of the back of the cylindrical cavity." The posterior part of the trochanter is therefore only an apophysis attached to the shaft for the insertion of the rotator muscles, and the mechanical function of the shaft and neck with reference to the resistance to strain is practically independent of it. The rarefying senile change affects this septum and may remove it so completely that it cannot be distinguished from the surrounding cancellous tissue. Sappey says that he has never seen this absorption go so far as to prolong the medullary canal into the neck. This comparative independence of the trochanter and the neck invalidates those theories of the mode of production of fractures which have been based upon the angle between their respective axes.

Fig. 263.

Neck of femur. (Bigelow.)

The capsule is usually attached to the femur in front along the spiral line, above to the neck a little short of its junction with the trochanter, behind to the neck itself about half an inch from the inter-trochanteric line, and below to the upper part of the lesser trochanter. In front and below, therefore, the neck lies entirely within the capsule, while above and behind its outer third or fourth part is external to it. These limits vary somewhat in different individuals. The synovial membrane does not follow the capsule closely to its insertion, but is reflected early from it to the neck, leaving a strip of the latter between the points where it joins the capsule and the synovial membrane which although intracapsular is yet extra-articular. The periosteum is thick and contains, especially in its upper portion, numerous bloodvessels which enter the head and neck by the large foramina found there. Of these vessels, one in particular, a branch of the internal circumflex artery, is of considerable size, runs along the upper portion of the neck and enters the head. Wilkinson King[1] has called attention to the fact that this portion of the periosteum is frequently left untorn in fracture of the neck, and he suggests that this arterial branch is probably the one which does the most to preserve the vitality of the head of the bone under such circumstances.

[1] Guy's Hospital Reports, 1844, p. 347.

Discussion as to the relative frequency of the different fractures of the neck of the femur has turned mainly upon the distinction between the so-called intracapsular and extracapsular ones, but the uncertainty of the diagnosis during life in a considerable proportion of cases is such that reliance cannot be placed upon records unverified by post-mortem examination, and the existence of an intermediate class of "mixed fractures" which may be arbitrarily added to one or the other makes even the tables of specimens somewhat uncertain. Malgaigne, who included the mixed among the intracapsular, considered these the more frequent, in the proportion of three to two, basing the opinion upon the examination of 103 museum specimens. It is questionable whether museum collections would represent the clinical proportions of the two varieties, since the intracapsular fractures attract more attention by their greater permanent disability and more commonly hasten death. There is reason to think that in the majority of cases the fracture takes place at the junction of the neck and shaft, and is accompanied by more or less penetration of the latter by the former. This is certainly true of fractures that occur in people who are less than 50 years old.

As a small contribution to the statistics of this subject I add the results of my personal experience during one year at the New York Almshouse, where fractures of the neck of the femur were quite common. I made post-mortem examinations in six cases; in two of them the fracture was purely intracapsular, at the narrow part of the neck, in three the fracture was at the junction of the neck and shaft, and in the remaining one in which the patient had survived the accident six months the neck had entirely disappeared, leaving only the hemispherical head and the shaft surmounted by the uninjured trochanter. From the symptoms in this case and the appearance of the specimen I believe that in it also the fracture was at the base of the neck. The ages were 65, 61, 82, 66, 40, and 70 years in the order in which the cases have been mentioned.

Causes.—An important predisposing cause has been mentioned, the senile rarefaction which begins usually after the 50th year and is more marked in females than in males.

The common immediate causes are slight falls upon the knee, the side of the thigh, or buttocks; less common are stumbles, missteps, an effort to avoid falling, or even, according to Sir Astley Cooper, the slight jar caused in stepping down to a lower level, as from the curbstone to the crossing.

It is probable that the action of the muscles or the strain exerted through the ligaments in extreme positions of the limb is a more frequent cause of fracture than is generally supposed, and that the fall is sometimes the consequence rather than the cause. A number of cases are on record in which the bone has been broken in this manner, and by efforts so slight in some of them that they might easily have been overlooked if a fall had been associated with them. Malgaigne indeed goes so far as to say that he believes most intracapsular fractures are produced, even in falls, by exaggerated movements of the thigh, adduction, abduction, or rotation. The efforts which have been made to explain different varieties of fracture by differences in the direction of the blow or in the point at which it has been received have not been satisfactory

either as a demonstration or as an aid in diagnosis. Few patients are able to tell exactly how they have fallen, and even if they could do so there would still be enough uncertainty concerning the extent to which muscular action had intervened to vitiate the conclusions that might otherwise be drawn from the circumstances of the fall. At the same time it should be said that attempts to produce the fracture in cadavers by blows upon the knees have always failed, while blows upon the trochanter usually succeed, the fracture being invariably at the junction of the neck and shaft if the body is that of an old person.[1]

Sir Astley Cooper (loc. cit., p. 155) tells of a woman who turned suddenly while standing; an irregularity in the floor kept the foot from following the movement of the body, and this was sufficient to break the neck of the femur. He tells also of a woman, 83½ years old, who, while walking across the room, accidentally placed her cane in a hole in the floor and lost her balance; she tottered, but was saved from falling by those standing near her, and found she had broken her thigh. At her death, fifteen months afterwards, the fracture was found to have taken place at the junction of the neck and shaft, with deep penetration of the former into the latter. (Loc. cit., p. 177, Case 90.)

Earle[2] mentions a case in which "the neck gave way within the capsule from a mere muscular effort in emptying a pail of water, and twisting the body and pelvis at the same moment, while the lower extremities remained fixed."

Dupuytren[3] refers to the case of a young negro, in whom the neck of the femur was broken by the tetanic contraction of his muscles, but the case is doubtless the one quoted by Malgaigne, Gurlt, and others, and as the fracture was compound, it is probable that the bone was broken below the trochanter (see Chap. IV. p. 94).

Malgaigne (loc. cit., vol. i. p. 666) produced a fracture by forced abduction of the thigh in an attempt to dislocate the head of the bone forward and downward. The cadaver was that of an individual 81 years old. He also saw a fracture caused in an old man in an effort to save himself from falling by leaning to one side. The effort was accompanied by sharp pain in the hip. He speaks of this as a fracture by exaggerated *adduction*, but gives no other details. Verneuil produced a fracture at the junction of the neck and shaft while trying to reduce a dislocation; the patient was an old man.

Linhart[4] was able to break the neck of the femur by adducting the thigh and then forcing the body backward so as to put the ileo-femoral, or Y-ligament, upon the stretch; and Riedinger[5] and Stetter[6] have recently published cases in which the injury occurred in like manner, the patients having bent suddenly backward to save themselves from falling. One was 60, the other 14 years old.

Anatomical Varieties.—The division of these fractures into *intracapsular* and *extracapsular* which is supported by the authority of Sir

[1] Hennequin, Des Fractures du Fémur, p. 627.
[2] Practical Observations on Surgery, 1822, p. 20.
[3] Leçons Orales, vol. ii. p. 94.
[4] Deutsche Gesellschaft für Chirurgie, 1875.
[5] Centralblatt für Chirurgie, 1875, p. 817. [6] Idem., 1877, p. 561.

Astley Cooper and Dupuytren and most of their contemporaries is defective anatomically, because of the mixed fractures for which it makes no formal provision and which are included sometimes in one and sometimes in the other;[1] and is objectionable clinically, because the relations of the fracture to the insertion of the capsule do not affect the symptoms and the prognosis so much as some other differences do, and because the differential diagnosis is impossible in a considerable proportion of cases. These objections have been urged by many surgeons; among them Clo quet, Gosselin, Bigelow, Duplay, Bryant, and Lossen may be mentioned as representatives of different countries and periods, some of whom have formally rejected the classification and substituted for it one based largely upon the presence or absence of impaction. No one can deny the great clinical importance of impaction and its influence upon the prognosis, but the condition to which the term is applied in fractures of the neck of the femur is not, in my opinion, such as should be made the basis of a classification, for the penetration of the fragments is not ordinarily such as fixes them closely together, but is rather an accident of the fracture, one which may or may not be superadded to it, and which is at the mercy of careless handling, of muscular spasm, or perhaps even of the manipulation necessary to make the diagnosis. Prof. Bigelow's[2] classification, which is briefly "Impacted fracture of the base of the neck, and unimpacted fracture of the rest of the neck," has the great merit of making an important clinical distinction, and also recognizes an anatomical feature, the position of the fracture at the junction of the neck and shaft, which is the essential characteristic of the largest division of these fractures.

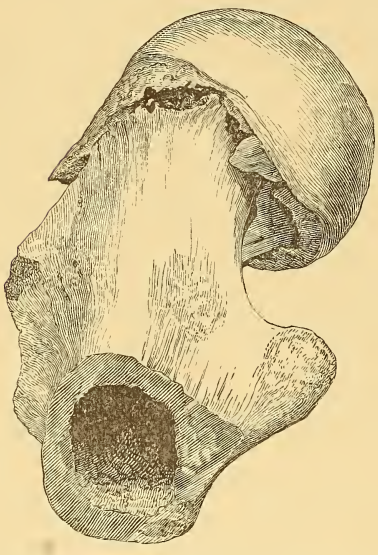
The distinction made by Sir Astley Cooper was actually between fractures at the narrow part of the neck (intracapsular) and fractures at or near the base of the neck (extracapsular and mixed), and it is not to be denied that these two varieties differ considerably from each other in their symptoms, and very notably in their prognosis. The objection is that the names applied to them have been misleading, and the distinction has lost the sharpness which it possessed in the minds of those who first made it, and therefore, while appreciating highly the desirability of retaining names sanctioned by long use, I have yet thought it best, in view of the general recognition of the defects of this classification, to use terms that define the anatomical position of the fractures somewhat more sharply. I shall therefore describe separately (*a*) *fractures of the small part of the neck* (*intracapsular*) and (*b*) *fractures at the base of the neck* (*extracapsular* and *mixed*).

[1] Thus Sir Astley Cooper (loc. cit., p. 148) defines as *extra-articular* "a fracture external to the ligament through the neck of the thigh bone, at its junction with the trochanter major. . . . . This is often in part within, and in part external to, the capsular ligament." While Malgaigne (loc. cit., p. 660) says "Il est à noter que plusieurs de ces fractures obliques se prolongent en dehors au delà des limites de la synoviale, et constituent en quelque sorte des fractures *mixtes*, à la fois intrà et extrà-capsulaires. Mais comme elles ne diffèrent pas sensiblement des fractures intràcapsulaires avec conservation d'une partie du périoste, je les comprendrai dans la même étude."

[2] The Hip, p. 126.

(*a*) *Fractures of the Small Part of the Neck* (Syn. Intracapsular fractures ; fractures of the anatomical neck).—The line of fracture may be transverse, oblique, or irregular. The surface of the fracture is almost always irregular, a large cone of spongy tissue presenting on one fragment, usually the head, and a corresponding depression on the other. As a result of the interlocking of their irregularities or of the penetration of one fragment by the other, the pieces may be retained in contact with each other or even so firmly impacted that considerable force may be required to separate them, as in a case quoted by Bigelow (loc. cit., p. 131), and represented in fig. 264. This impaction or close interlocking is doubtless very rare. The line of fracture in rare cases passes partly through the head of the bone, and sometimes the fracture is comminuted.

Fig. 264.



Impacted intracapsular fracture of the neck of the femur. (Bigelow.)

The periosteum of the neck is usually left untorn over a portion of the periphery, the seat of which varies considerably in the different cases. In a specimen in my possession the untorn portion is nearly an inch in width, and is situated at the lower and posterior part; in other reported cases it has been behind, behind and above, and above and in front. A case of complete preservation of the periosteal sheath was reported by Mayor.[1] The patient was an old man who fell while walking, and was brought to the hospital. The clinical account is very brief, stating only that he presented the well-known signs of fracture near the hip-joint, and that the diagnosis could be made on simple inspection of the position of the foot. It is probable, therefore, that eversion of the limb was marked. He died in a week. On opening the joint no sign of fracture could be seen, but after scraping off the periosteum of the neck the fracture was found "immediately behind the head and in the form of an almost imperceptible fissure."

A somewhat similar case is reported by Stanley,[2] and, although the fracture appears to have been rather at the junction of the neck and shaft, I quote it here to complete the subject. The patient was a man 60 years old who fell in the street and presented no symptoms of injury at the hip except pain. He died in the fifth week of inflammation of the bowels. "The head and neck of the bone were sawed through their

[1] Gazette Médicale, 1834, p. 612.
[2] Med. Chir. Transactions, vol. xiii., 1825, p. 511.

middle, and in each portion a dark line, evidently occasioned by the effusion of blood, was seen extending through the bone at the basis of the neck. A fracture was discovered extending along this line; but the broken surfaces were in contact, and the synovial and fibrous membrane covering the neck of the bone was uninjured."

Partial fractures were first reported by Colles,[1] but his interpretation of the cases, which are given with scanty details, was questioned by R. W. Smith; and in another alleged case reported by Adams the same surgeon proved by maceration of the specimen that the fracture was complete.

A more probable case, although not belonging in this class, is one reported by Tournel in 1837, and quoted by Malgaigne (loc. cit., p. 43). A man, 83 years old, fell and was unable to rise. There was no shortening, no crepitation, nothing but pain in the hip increased by the least movement, swelling, and inability to move the limb. The diagnosis of intracapsular fracture without displacement was made, and Desault's long splint applied. On the 28th day, the pain having ceased and the limb maintaining its full length, the diagnosis was changed to contusion and the splint removed. A fortnight afterwards there was shortening and eversion; diarrhœa ensued, and the patient died three and a half months after the fall. The autopsy showed an incomplete fracture between the base of the neck and the trochanter, constituting a long crack which ran down in front and behind from the digital fossa to points a little below the lesser trochanter, which remained attached to the neck. Below the lesser trochanter was a sort of bony bridge where the bone had remained unbroken. The broken surfaces were not in immediate contact but were united above by an interposed reddish, bony substance.

The shortening noted in this case must have been an error of observation if the anatomical description is correct.

Another case was reported by Wilkinson King,[2] the patient was a man 72 years old, and died on the 54th day of pneumonia. No mention is made of the clinical symptoms. "The neck of the left thigh bone was nearly divided by fracture at its narrowest part. All that seemed to retain the fragments in union was less than one-third of the shell superiorly and anteriorly. The head was deflected backwards, and the buttress of the neck, which was too thin, was driven into the cancelli about a third of an inch. The only trace of new ossification is a point on the base of the buttress. There is no certain repair even of the bent portion of the shell above." The accompanying figure, which represents a section of the head and neck, shows a line of crushing extending nearly across the neck close to the head. Considering the age of the patient, the extent of the displacement, and the length of the survival, it seems probable that the fracture originally extended entirely across, but with no displacement except an angular one made possible by the crushing of the tissue along the line of fracture. The nearer the apex of the angle the less would be this crushing, and the minimum at the cortical layer might easily be repaired without leaving any trace.

[1] Dublin Hosp. Rep., vol. ii. p. 334, Cases 7, 8, and 9.
[2] Guy's Hosp. Reports, 1844, p. 352.

In an interesting case that came under the care of Prof. Bigelow (loc. cit., p. 138) a spiral fissure began at a fracture eight inches below the trochanter, "winds upward and inward to the front of the bone, crossing the anterior intertrochanteric line midway between the trochanters; thence vertically upward to the outer edge of the cartilage; thence transversely across the top of the neck to its posterior surface; thence vertically down behind the neck to a point half an inch from the lesser trochanter, terminating on the under side of the neck half an inch from the point where the fissure crosses the intertrochanteric line in front. The elastic bony pedicle thus formed allows a slight springing motion of the head, but maintains it firmly in place."

Some of the French writers refer to cases by Sabatier and Hervez de Chégoin, but I have been unable to verify them.

Separation of the epiphysis, of the head from the neck, has been suspected sometimes, and verified once by examination. Bony union of the part takes place between the seventeenth and twenty-first years, and in the few cases of fracture of the neck of the femur that occur in patients of this age, or younger, the question whether the fracture may not follow the epiphyseal line will naturally arise. Dr. Hamilton quotes six cases in which this injury was suspected; Mr. Hutchinson[1] mentions three others, one of them having been under his own care; and Spillmann[2] quotes one observed by Sabatier and another by Verduc. The case verified by examination, is reported in the *Bulletins de la Société Anatomique*, 1867, p. 283. The patient was fifteen years old, and was run over by a wagon. The symptoms were shortening, eversion, and inability to move the limb. The patient died in a few hours. The separation was complete along the epiphyseal line, and the head was attached to the neck only by a strip of periosteum two millimetres wide. The periosteum was stripped up on the inner and lower part of the neck, and the capsule was torn at its inner portion.

Dr. Johnson[3] gives the history of a case under the care of Dr. Wood, which may have been either a separation of the epiphysis or a pure intracapsular fracture. The patient was a girl sixteen years old, who had been caught between the wheels of two wagons. The fracture failed to unite, and at her death, three years later, the head and neck were found very soft and partly absorbed. If the lesion was a fracture the case deserves mention because of the patient's youth.

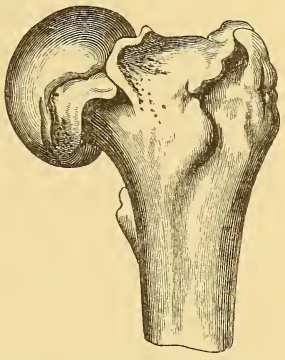
The usual *displacement* is of the shaft upward, and it is sometimes accompanied by laceration of the capsule; it usually takes place gradually during the week following the receipt of the injury, and rarely exceeds one inch, except after the lapse of a long period of time. I have seen it in one case reach two inches in the course of the second month. If impaction takes place the head may be twisted about its axis, as in fig. 264, or there may be some overlapping, as in fig. 265.

The *symptoms* are inability to raise the limb or to bear the weight of the body upon it, eversion, shortening, at first slight, afterwards increas-

[1] Med. Times and Gazette, 1866, i. p. 195.
[2] Dict. Encyclopédique, art. Cuisse, p. 238.
[3] N. Y. Journal of Medicine, 1857, p. 303.

ing, crepitation on manipulation, and possibly the sense when the limb is gently rotated that the trochanter moves upon a shorter radius than usual. These symptoms will be considered more in detail hereafter, but a word of caution is needed with reference to two of them, eversion and inability to use the limb.

Fig. 265.



Impacted fracture within the capsule. (Smith.) (See p. 502.)

Inversion of the foot has been observed in not a few cases, and in some has led to the diagnosis of dislocation and treatment by extension with pulleys. A remarkable instance of this was reported by Bevan;[1] it was observed in the body of an old woman brought to the dissecting-room. There was half an inch shortening, which could be easily increased by pressure on the heel to one and a half inches. The foot was slightly rotated inward, and could be turned in that direction until the toes pointed directly backward. Outward rotation was possible to the usual extent. The fracture was an old one, and the neck was entirely absorbed.

Similar cases in which the diagnosis was verified by post-mortem examination have been reported by many surgeons. In Stanley's[2] case the patient was a middle-aged man, and the injury was caused by a fall in the street, the hip striking against the curbstone. There was one inch shortening, and inversion; the injury was thought to be a dislocation, and extension was made. The fracture was oblique and entirely within the capsule. In most of the cases the exact position of the fracture has remained in doubt, and the subject, therefore, will be referred to again in the section on Symptoms and Diagnosis.

In some cases the patient has been able to move the limb quite freely immediately after the receipt of the injury, and even to walk upon it with more or less limping and pain. The following are among the most marked illustrative cases verified by post-mortem examination.

A feeble, sickly woman,[3] fifty-six years old, was admitted to the hospital with erysipelas of the left thigh. Redness and swelling extended down to three inches above the patella, and fluctuation was evident on the outer and upper part of the thigh. The swelling had appeared three days before admission to the hospital, and had been preceded by rigors. Three months previously she had fallen on her left side, and from that time she had had a slight halt in walking, but the injury had not kept her from her usual occupations.

She suffered much pain in the thigh, measurements could not be made, and the limited handling that was possible caused no crepitus. The abscess was punctured and discharged freely until her death on the eleventh day. The neck of the femur was found to be broken within

[1] Dublin Quarterly Med. Journal, 1850, vol. ii. p. 312.
[2] Med. Chir. Transactions, vol. 13.
[3] McTyer, in Glasgow Med. Journal, 1831, p. 52.

the capsule, and the abscess communicated with the joint through a laceration in the capsule. No other details are given.

Dr. Wm. Hunt[1] reported a remarkable case. The patient, a man 26 years old, was struck across the upper portion of the left thigh and groin by a heavy piece of timber and fell to the ground. He suffered much pain all night and came the next day to the hospital, travelling some distance in the cars and walking from the station to the hospital, a distance of more than a furlong, with the aid of a stick. The symptoms were pain, eversion of the limb, shortening of half an inch, and deep crepitus. There was a large bruise on the upper and outer aspect of the thigh over the trochanter and the anterior superior spinous process of the ilium. A pelvic abscess formed, and he died on the twenty-seventh day.

"The neck of the femur immediately behind the head was broken directly across, the lines of fracture being completely within the capsule of the joint."

One of my own patients, a man 65 years old, fell down a flight of steps, rose without assistance, walked to and down the next flight, and then suddenly found his left leg powerless. Two days afterwards I saw him and found half an inch shortening and eversion. He died in the third week of erysipelas. The fracture was almost directly transverse and close to the head, and a strip of periosteum one inch wide on the under side of the neck remained untorn. (See also the case quoted below from R. W. Smith, p. 502.)

Repair.—The possibility of the repair of an intracapsular fracture of the neck of the femur by bony union has been the subject of much discussion for more than fifty years. It began with the assertion by Sir Astley Cooper that union was extremely rare, and indeed practically impossible in the common form of the injury, that in which the periosteum is torn. Sir Astley's opinion was generally understood to be that bony union was impossible under any circumstances, and as such found its principal opponent in Dupuytren. Subsequent authors have ranged themselves upon one side or the other of the question, according to their interpretation of certain specimens of alleged repair by bony union preserved in public museums or in the possession of private individuals. The number of these specimens and of reported cases is quite large, probably between forty and fifty, and the questions that arise concerning them are: 1st. Has the bone been broken, or is the condition due only to absorption of the neck? 2d. Was the fracture a pure intracapsular one? 3d. Is the union bony?

The first question arises in only a few cases, some specimens found in the dissecting room without history. Sir Astley Cooper refers to two found by Mr. Stanley in one subject, and evidently considers it more unlikely that a man should break both thigh bones and get well than that senile absorption should take place in both.

The third question arises only in those cases in which the specimens have not been examined thoroughly by division and maceration. Fibrous union has sometimes been so close and firm that it has been thought to

[1] Philadelphia Med. Times, October 26, 1872, p. 49.

be bony. The technical significance of these doubtful cases is quite distinct from their practical bearing, for the limb can be made as useful by close fibrous union as by bony union, and therefore, even if the latter is considered impossible to be obtained, the inference that immobilization is useless and treatment unnecessary is unjustifiable.

The second question is the one that is most difficult to be answered; given a specimen with history of fracture and bony union, where did the line of fracture run? The answer to the question is made difficult by the extensive absorption of the neck and by uncertainty as to the original point of attachment of the capsule. My impression is that the importance of the doubt has been magnified by the preconceived opinion of many observers and writers, that union is practically impossible, an opinion which leads them to demand much more strict and definite proof than is ordinarily required in similar questions. The disappearance of the neck by crushing or absorption, or its impaction into the shaft brings the head close to the trochanters, and the changes wrought in the appearance and compactness of the tissue by the process of repair make it difficult to determine the relations and belongings of the parts.

The question is not of sufficient general importance to make it desirable to examine here the testimony for and against each alleged case. I quote the descriptions of five cases in illustration, two of which, the third and fifth, have not been quoted in the text books and discussions.[1]

Stanley's case.[2] A lad 18 years old fell from a cart, striking upon his right hip. He was unable to move the limb; it was bent to a right angle with the pelvis, could not be extended, and abduction was difficult. There was eversion, no shortening, no crepitus. He died three months afterwards of smallpox. The capsule was thickened, the ligamentum teres uninjured; a line of fracture extended obliquely through the neck entirely within the capsule; the neck was shortened, the head approximated to the trochanter. The fractured surfaces were in close apposition and united nearly in their whole extent by bone. There was an irregular deposit of bone beneath the periosteum along the line of the fracture.

Swan's case.[3] Mrs. Powell, above 80 years of age, fell down Nov. 14,

[1] For the convenience of those especially interested in the subject, I add the following references to the principal sources of information concerning the cases and specimens: Med. Chirurg. Transactions, vols. xiii. and xviii.; Sir Astley Cooper, Fracts. and Disloc.; Dupuytren, Leçons Orales, vol. ii. p. 115; Malgaigne, Fractures, vol. i. p. 677; R. W. Smith, Fractures in the Vicinity of Joints, p. 52; Hamilton, Fracts. and Disloc.; Gurlt, Knochenbrüche, vol. i. p. 307; Massey, in Am. Journal Med. Sciences, 1857, i. p. 299; Packard, in the same, 1867, ii. p. 377; March, in Trans. Med. Soc. of State of New York, 1858, p. 191; Johnson, in N. Y. Journal of Med. 1857, p. 295; Geo. K. Smith, in Med. and Surg. Reporter, Phila., 1862, vol. vii. p. 244.

The earliest recorded case with which I have met is one quoted by Earle (Practical Observations in Surgery, 1823, p. 97) from Christopher Henry Erndleus, *Relatio Itineris Anglic. et Batav.* p. 86, date not given, and as the case is not referred to by any later writer, I quote the description in full. "Talem fracturam his meis oculis vidi et manibus palpavi in cadavere fœminæ nosocomei muliebris Amstelodamensis sociœ in quâ tractu temporis, fractura illa cervicis ossis femoris dextri per callum coaluerit iterum, fœmina tamen exinde per omnem ætatem ad mortem usque clauda. *Callus pollicis latitudine sub ipso capite magno ossis femoris extabat, nulla autem in ligamentis ac tendinibus musculorum læsio vel præter naturalis constitutio erat.*"

[2] Med. Chir. Trans., vol. xviii. 1833, p. 256.

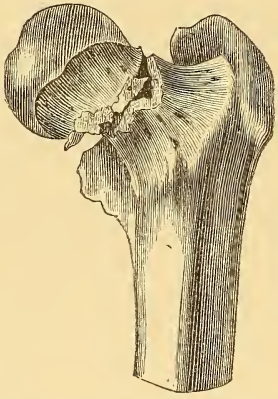
[3] Swan on Dis. of Nerves, p. 304, quoted by R. W. Smith, loc. cit., p. 59.

1824. Sir Astley Cooper, who saw her soon after, believed that there was a fracture of the neck of the femur, although there was no appreciable shortening of the limb, and only a slight inclination of the toes outward, no crepitus. The patient died about five weeks afterwards. The fracture was found to have been entirely within the capsular ligament, and the greater part of it was firmly united. After section through the fractured part, a faint white line was perceived in one portion of the union, but the rest appeared to be entirely bone.

Supposing the diagnosis in this case to have been correct, union in five weeks can be explained only on the supposition that the fracture was without displacement and without laceration of the periosteum.

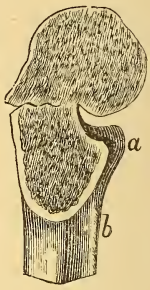
Gurlt[1] describes a specimen contained in the museum at Giessen (figs. 266 and 267). "The fracture runs obliquely through the neck of the femur; in front it is three-fourths of an inch from the base of the neck,

Fig. 266.



Pure intracapsular fracture of the neck of the femur. Bony union. (Gurlt.)

Fig. 267.



Oblique section of the specimen shown in fig. 266. (Gurlt.)

posteriorly a little less. The head of the bone is displaced somewhat backward and downward, and is united by bone, although the line of fracture is still visible in places.

Brulatour's case.[2] A man, 47 years old, was thrown from his horse; he arose and walked a step or two, but the attempt caused great pain and he fell again. There was shortening of the limb, eversion, crepitation. Extension was kept up for two months. Three months after the accident he was able to walk with a cane, and subsequently recovered full use of the limb. He died nine months after the accident.

The capsule was found a little thickened, the neck of the femur shortened, an irregular line surrounding it and showing the direction of the fracture, and a considerable bony deposit at the bottom of the head of the femur and at the external and posterior part. On section the line of union indicated by the callus was smooth and polished as ivory.

[1] Loc. cit., vol. i. p. 308.
[2] Med. Chir. Trans., vol. xiii., 1825, p. 513.

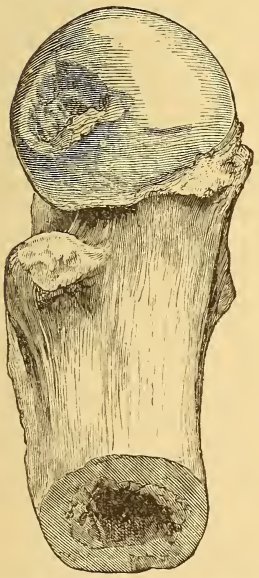
The line of callus denoted also that the bottom of the head of the femur had been broken at its superior and posterior part.

Cushing's case.[1] A woman, 70 years old, fell upon her side while reaching to wind up a clock. There was no obvious displacement but the disability was such as to leave no doubt of the existence of a fracture. She was kept in bed for two and a half months with the knee flexed over two pillows, and then began to sit up with the leg extended. Crutches were used for six months, then a crutch and cane, and then for the last two and a half years she was able to go about the house unaided; there was no shortening and but little limping. During the first few weeks there was much pain at the seat of the injury and in the limb, which gradually became atrophied. She died about five years after the accident.

The neck of the femur (fig. 268) is short and thick, the line of fracture corresponding nearly with the edge of the articular cartilage. The head of the bone has been depressed so that the neck is now nearly transverse; the head is also bent obliquely backward and downward towards the lesser trochanter, and the shaft thus rotated outward. In front, the neck of the bone projects beyond the articular cartilage, while behind it is buried beneath it; it is thus impacted posteriorly into the head, which in bending backward opens a fissure filled in front with an irregular bony callus.

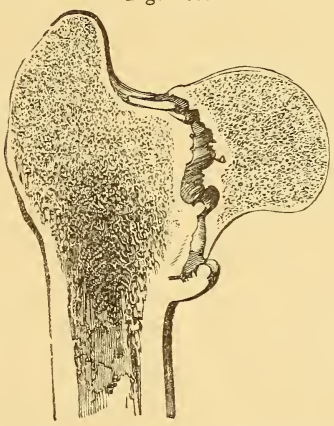
Prof. Bigelow thinks that the fracture when recent resembled that represented in fig. 264.

Fig. 268.



Impacted intracapsular fracture. (Bigelow.)

Fig. 269.



Fracture within the capsule. Close fibrous union.

Other specimens and reported cases show that while complete failure of union or scanty fibrous union is the rule it is apparently due mainly to the mobility of the parts upon each other or their displacement. The specimens show that the head can preserve its vitality perfectly, that

[1] Bigelow, the Hip, p. 133.

the fractured surfaces can become united by a firm fibrous bond (fig. 269), or, failing that, that their tissue may become eburnated. The capsule usually thickens and sometimes becomes closely adherent to the periosteum lining the neck, and thus obliterates all the outer portion of the original cavity of the joint. This was the condition in two cases reported by Colles,[1] and there was actually a false joint between the fragments, the surface of the lower one being hollowed out to receive the upper. Sometimes the capsule ossifies in part. The two following cases are quoted to show the ability of the upper fragment to produce granulations and to illustrate close fibrous union without absorption of the neck. They are both taken from R. W. Smith, cases 59 and 58. See also his cases 11 and 16 for examples of eburnation.

A man, fifty-two years old, was admitted to the City of Dublin Hospital with an intracapsular fracture of the neck of the femur, and died of bronchitis on the sixteenth day. Very little synovia was found in the hip-joint; a layer of lymph covered the entire inner surface of the capsule, was closely adherent to it, and vascular; at several points it adhered to the head and neck of the femur.

The fracture was entirely within the capsule, passed in a tortuous direction downward and outward to the compact tissue at the under part of the neck, where it ran very obliquely downward and outward, thus leaving connected with the upper fragment in this situation a sharp wedge-shaped portion of the compact tissue of the bone, which overlapped the lower fragment. The cervical ligament [periosteum] torn in front was perfect behind and below; the surface of each fragment was highly vascular, and several shreds of lymph connected them; in fact, a thin layer of lymph was effused between the opposed surfaces of the fracture, on separating which it was drawn out into the thin and delicate bands above mentioned. The fracture in this case was caused by a fall directly on the most prominent external part of the trochanter major, and the patient walked a few yards after the receipt of the injury. The foot was everted and the limb shortened exactly half an inch.

A woman, eighty years old, fell upon her left hip while walking across her room and was unable to rise. She was seen an hour afterwards, complained of severe pain in the region of the joint, and could not move the limb which was slightly *inverted*, and any attempt to evert it caused great pain. A fracture of the other leg that had united with much deformity made it impossible to recognize shortening if it was present. She died eight weeks afterwards, having regained some control over the limb, which remained inverted.

The fracture was close to the head of the bone above, passed thence downward and inward, leaving a portion about half an inch in length of the under part of the neck attached to the head. The head was displaced downward, overlapping the neck below and behind, and being overlapped by it above and in front (see fig. 265). There was thus a mutual impaction of the two fragments, and they were further maintained in contact by a dense, fibrous tissue, which adhered closely to the broken surfaces.

[1] Dublin Hosp. Reports, vol. ii. p. 334.

In view of the closeness of the fibrous union shown in some specimens, of the occasional usefulness of the limb after fracture, and of the great uncertainty of the diagnosis in many cases, an uncertainty that is recognized by all surgeons, and abundantly testified to by them, the practical side of the question of the possibility of bony union after fracture of the narrow part of the neck, and entirely within the capsule, is not very important, for the treatment, or rather its duration, will depend mainly upon the patient's strength and general condition, and the prognosis will always be guarded.

There is, however, another side to the question, an interest in which is legitimate, even if apparently without practical value. Even if we disregard all existing specimens of alleged bony union, the possibility of such union must, I think, be admitted, because of the demonstrated fact that the head preserves its vitality, and has shown its ability to produce granulations and bone; the former proved by the examples of fibrous union, the latter by eburnation or condensation of its spongy tissue. More than this, it has been shown even that pieces of bone completely detached may regain complete vascular connection and bony union with the piece from which they have been broken, and, therefore, it is proper to assert that it is theoretically possible for the completely detached head of the femur to regain connection with the neck, much more so for one that has preserved more or less of its fibrous connection. Fibrous union after fracture is demonstrated by several specimens; ossification is merely the ultimate step in the evolution of the granulations arising from bone, and it has been shown in the study of failure of union, of pseudarthrosis, that the arrest of the process is commonly due to lack of immobilization, defective contact, or constitutional peculiarities of which old age is not one. Prolonged complete immobilization of a fracture of the neck of the femur is practically impossible, accurate coaptation of the fractured surfaces is a matter of chance, and the reason of the habitual failure to get bony union is to be found in the inability of the surgeon to meet the two principal indications of treatment, coaptation and immobilization, not in any inability of the tissues themselves to do the work required of them. The absence of the enveloping mass of soft parts which are found about other fractures, and which contribute so efficiently to their repair, constitutes an additional difficulty in this case, but does not make repair impossible. The history of impacted fractures, or fractures with crushing, shows that spongy bone is capable of repairing its own injuries without aid from the periosteum or the overlying soft parts. In the two cases quoted at the beginning of this section, Mayor's and Stanley's, in which the periosteum remained entire and there was no displacement, the presumption is entirely in favor of the possibility of repair, and it is in such cases that the diagnosis would subsequently be most doubtful, as in Swan's case. The *probability* of repair is greatest under such circumstances, and diminishes as the displacement increases.

The common result of this fracture is permanent disability, more or less complete. The patient is sometimes bedridden because of the pain provoked by motion and of the general feebleness which makes it impossible for her to get about with crutches; or limited use of the limb may be possible with the aid of a cane, or its place may be supplied by

crutches. The foot remains everted, the limb shortened. In exceptional cases the patient may have very good use of the limb, even when union has failed entirely, as in the following case reported by Gosselin.[1]

A woman, 66 years old, received a fracture of the thigh which was treated simply by rest in bed for three weeks. After this time she walked with crutches, and left the hospital seven weeks after admission, using only a cane, and able to walk for fifteen minutes at a time; the improvement continued and she became able to walk half an hour at a time, still with the aid of a cane, and was considered, by Gosselin, an example of good consolidation after a fracture, the exact position of which, whether intra- or extra-capsular, he had not felt able to determine positively. Seven or eight months later she returned to the hospital and died. The autopsy showed an intracapsular fracture, not united. The fragments were held together only by a few strips of periosteum, and moved upon each other, forming a pseudarthrosis resembling an arthrodial joint.

The *diagnosis and treatment* will be considered subsequently in connection with those of fracture at the base of the neck. There are no signs absolutely distinctive of fracture at the narrow part of the neck in contradistinction from those of the base. The question turns usually upon the *degree* of certain symptoms, and upon probabilities, both of which are untrustworthy as aids in diagnosis.

(*b*) *Fractures at the Base of the Neck* (Extracapsular fractures).—The line of fracture follows ordinarily the junction of the neck and shaft quite closely, that is, it coincides with the spiral line in front and the inter-trochanteric line behind as they pass between the great and lesser trochanters. It may extend downward and detach the lesser trochanter from the shaft, leaving it attached to the neck, or go even lower and separate a part of the shaft. At its upper part it may deflect to either side, crossing the outer part of the neck or traversing the upper part of the great trochanter.

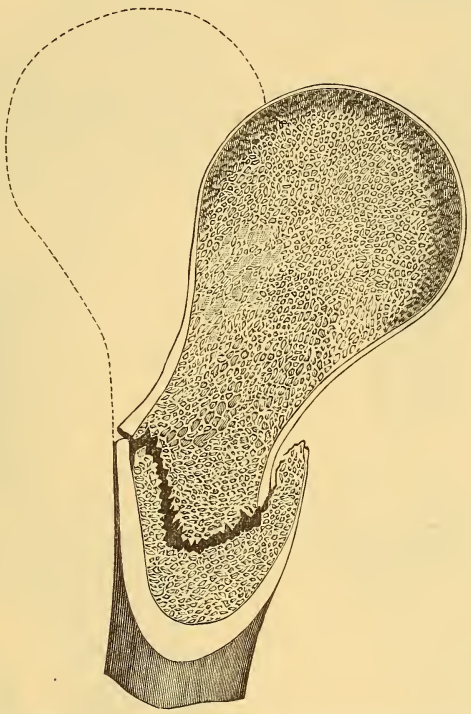
In the majority of cases other lines of fracture traverse one or both trochanters, splitting off one or two pieces, usually from the posterior surface of the great trochanter, or comminuting it completely. Malgaigne thought simple fracture, division into only two fragments, was exceedingly rare; the only case of which he knew, excluding two in which the fracture crossed the trochanter horizontally, was one described by R. W. Smith (loc. cit., Case 34), and as even in this two fragments are broken off the trochanter behind it is evident that he believed considerable comminution to be the rule. Hamilton refers to two similar specimens, one in Dr. Mütter's, the other in Dr. Neill's collection; and in one of the six autopsies to which I referred above there was no splintering, and in another the fracture was almost identical with the one quoted by Malgaigne from Smith. The first of these two specimens was presented to the New York Pathological Society, in January or February, 1879.

The common fracture is that in which the neck is bent backward with crushing of the posterior part or penetration of the neck into the tro-

[1] Clinique Chirurgicale, vol. i. p. 360.

chanter. Prof. Bigelow[1] directed especial attention to this bending backward and impaction (fig. 270) as the important features of the most common form of fracture in this region, the symptoms of which are pain and tenderness, disability, shortening and eversion, however slight,

Fig. 270.



Impacted fracture at the base of the cervix femoris, with bending of the head backward. (Bigelow.)

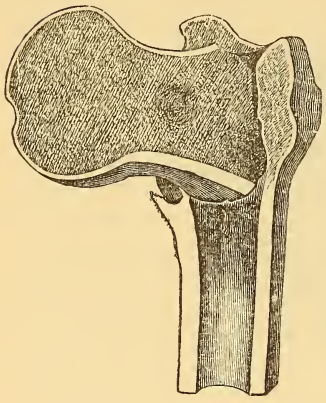
absence of crepitus, and rotation of the trochanter about the head of the bone as a centre, and he described the displacement as a rotation of the head and neck backward and downward upon the portion of the anterior wall corresponding to the spiral line uniting the trochanters as upon a hinge. This displacement accounts for the eversion and slight shortening.

A certain amount of misapprehension has resulted from the use of the word *impaction*. Impaction, in the sense of penetration and fixation, is, I think, comparatively uncommon; while crushing, with or without penetration or much splitting of the trochanter, is the rule. The penetration or crushing may be limited to the posterior part (this, as has been said, is the most common condition), or the neck may turn upon its upper portion, making that the hinge, and sink its anterior, posterior, and lower walls into the substance of the trochanter (fig. 271), or the neck may

[1] The Hip, p. 118, and Boston Med. and Surg. Journal, vol. 92, 1875, pp. 1 and 29.

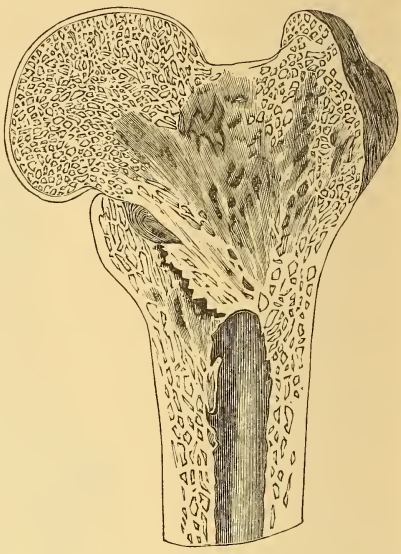
be driven bodily into the trochanter without changing its direction, and may even penetrate to the opposite wall. In exceptional cases the lower fragment may penetrate the upper one.

Fig. 271.



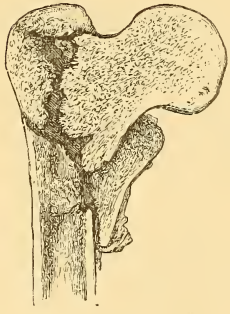
Impacted fracture of the neck of the femur without splintering. Vertical section.

Fig. 272.



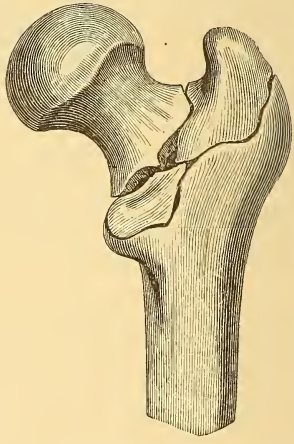
Repair after fracture of the neck of the femur. (Lossen.)

Fig. 273.



Comminuted fracture of the neck of the femur. (Bryant.)

Fig. 274.



Fracture of the neck of the femur with splitting of the great trochanter.

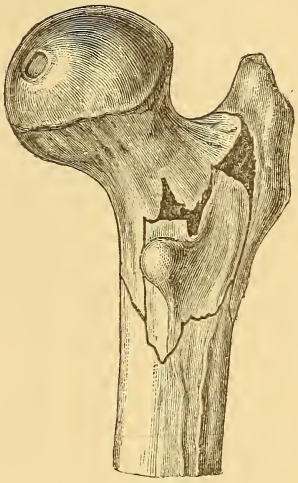
The splitting of the trochanter may be limited to one or two pieces broken off its posterior border (fig. 274), or it may be very general

(fig. 275). The extent of the splitting seems to be independent of the force that caused the fracture, extensive comminution being sometimes produced by a simple fall while walking, as in fig. 276, which is drawn from one of my own specimens.

In a few cases the angular displacement of the neck has been in the opposite direction, so that the limb has been rotated inward instead of outward. R. W. Smith (loc. cit., p. 128) describes one such specimen, and Bigelow (loc. cit., p. 128) another. In a number of cases inversion has existed when the fragments were not interlocked.

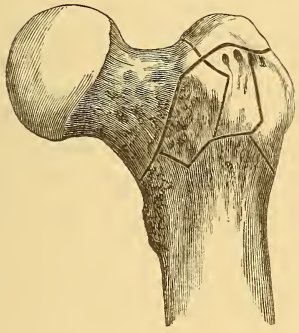
Partial, incomplete fracture was asserted by Adams[1] to be common. He thought that a fall upon the trochanter tended to enlarge the inferior angle between the neck and the shaft, to bring the two more nearly into line,

Fig. 275.



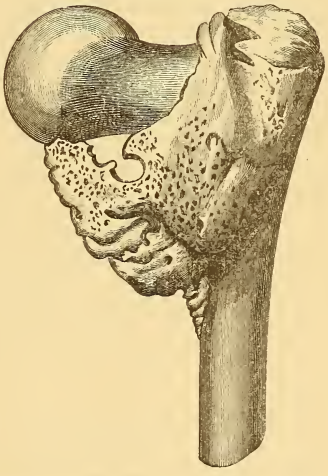
Comminuted fracture of the neck of the femur.

Fig. 276.



Comminuted fracture of the neck of the femur. Anterior aspect.

Fig. 277.



Exuberant callus after fracture of the neck of the femur. (Smith.)

and thus caused a fracture or crack of the lower wall of the neck, and that the fracture became complete in consequence of attempts to use the limb or of the contraction of the muscles. This theory, which seems to have made some impression at the time, has proved incorrect. The only known instances of partial fracture have been quoted in the preceding section, page 495.

The common symptoms are inability to move the limb, local pain, eversion and shortening more or less marked, and crepitus sometimes

[1] Dublin Med. Journal, vol. 6, 1835, p. 220.

to be felt on rotation or extension. They will be described in detail in a subsequent section, as will also the prognosis and treatment.

Repair.—In most cases bony union takes place, and indeed the production of bone is often excessive (fig. 277) and interferes with the subsequent use of the limb. In one of Smith's cases (loc. cit., Case 51), fracture with penetration, the fragments were movable upon each other but could not be separated because of the new bone which had grown from the outer fragment and enveloped or interlocked the end of the inner one. The average period of time thought to be sufficient for consolidation, has been estimated at from forty to fifty days.

Symptoms of Fracture of the Neck of the Femur.—The symptoms of the fracture and the signs upon which the diagnosis must be made include not only the usual objective and subjective symptoms of fracture but also the history of the case, the nature and especially the slight degree of the violence which so often characterizes this injury.

Interference with Function.—As a rule the patient is unable to use the limb, and he is not merely unable to bear his weight upon it but he cannot even move it in bed. Exceptions to this have been already mentioned, and it is not particularly uncommon to see patients who, while lying on the back, can slowly flex the thigh upon the pelvis either by its muscles alone or with the aid of the hands, but they cannot raise the foot from the bed, the knee bends at the same time and the foot is drawn up towards the body. Most authors have mentioned cases in which the patients have walked for longer or shorter distances immediately after the injury, and in which the existence of a fracture has subsequently become very clear. Thus, Sabatier[1] describes two, Desault[2] is said to have seen several and to have published one, and Boyer[3] describes one in which the patient walked with the aid of a cane for several days. This is very exceptional, and it is sufficient to bear the possibility in mind to avoid the error of inferring that a fracture cannot be present because the patient is or has been able to use the limb.

The opposite error, that of supposing a fracture to exist because the limb has been disabled by a fall, can be easily made, because a simple contusion may cause eversion of the limb as well as ecchymosis and swelling, and in some cases fracture causes no other symptoms than these. Observation of the case for a few days will make the diagnosis clear.

Pain is always present. It is usually slight, or even absent, when the patient is at rest, but is readily excited by even slight communicated or voluntary movements. It is referred sometimes to the region of the trochanter, sometimes to the groin or inner and upper portion of the thigh. Sometimes pressure with the end of the finger detects a particularly sensitive point in the line of the neck in front just outside the great vessels.

The *posture* and *appearance* of the limb are so characteristic that it is sometimes almost safe to make the diagnosis by simple inspection. As

[1] Mém. de la Société Royale de Chirurgie, vol. iv., 1768, p. 638–9.
[2] Œuvres Chirurgicales, vol. i. p. 223.
[3] Malad. Chirurg., 4th ed., vol. iii. p. 261.

the patient lies upon his back the affected limb appears shorter than the other, everted, and slightly flexed and abducted, and conveys an impression of helplessness that is often very striking. The upper portion of the thigh is swollen in front and on the outer side, and ecchymoses appear after a day or two.

Eversion may be so marked that the foot rests entirely upon its outer border as the patient lies upon the back. In other cases it is so slight that, as Prof. Bigelow has pointed out, it is best recognized by comparing the extent to which the two feet can be *inverted.*

In exceptional cases the limb is *inverted;*[1] it is either found so on the first examination[2] or it becomes so after a day or two; Desault estimated the frequency of this symptom at one-fifth of all cases; in 60 cases tabulated by Smith eversion is noted 33 times, and inversion 7 times, in 1 it is said there was no rotation to either side, and in the remaining 19 the symptom is not mentioned.

The cause of the eversion is probably almost always mechanical: it is simply the effect of gravity acting upon the limb under changed conditions of support. It is favored by angular displacement of the neck of the bone when accompanied by impaction and fixation. On the other hand, eversion has been observed in cases of simple contusion, and in others of fracture in which there was no displacement of the fragments, no rupture of the periosteum even, and consequently no loss of support. When one lies upon his back a distinct, although slight, effort is required to keep the toes upright; the natural tendency of the limb is towards eversion, particularly if the knee is slightly flexed, and this tendency which is increased by anything that diminishes the activity of the muscles must be taken into account in those obscure cases where the diagnosis lies between a contusion and a fracture. The claim that eversion is due to contraction of the external rotators cannot be substantiated; the single fact that eversion becomes, if possible, even more marked after death is sufficient to show its incorrectness.

The cause of inversion is not so clear. Smith attributes it to the position of the fragments relative to each other, and says that in all the cases of inversion which he was able to examine post mortem he found the lower fragment in front of the upper one. This, however, does not

[1] According to Sabatier and Louis (Mém. de la Société de Chirurgie, vol. iv. 1768, p. 632 and 653) Ambroise Paré was the first to recognize the possibility of fracture of the neck of the femur, and it is singular that in his first case, supposed for two days to be a dislocation, the limb was inverted. The patient was an old woman and the fracture was recognized by the crepitation produced by attempts to reduce the supposed dislocation. Sabatier and Louis looked upon the statement that the limb was inverted as an error of observation or as meaning only that the foot was held nearer the other leg than the knee was, or as an error of the copyist. On the strength of this statement by Paré inward rotation of the limb seems to have been considered a classical symptom of fracture of the neck of the femur for more than a century.

[2] While these pages were going through the press I received from Prof. W. J. Conklin, of Dayton, Ohio, an interesting account of a case observed by him and published in the Columbus Medical Journal, November, 1882, in which marked inversion was present and persisted until the patient's death, four weeks after the accident. The patient was a woman 84 years old, and the fracture was caused by a fall from the stool backward upon the trochanter. The post-mortem examination showed an impacted fracture at the base of the cervix femoris.

always explain the symptom when the fracture is of the narrow part of the neck, intracapsular, as in Stanley's case quoted above (p. 497), although it may do so in some, as in the case observed by Goyrand[1] where the neck had slipped behind the head and was fixed between it and the capsule.

The diagnostic value of the posture of the limb, as regards eversion or inversion, is not very great, for inversion is a symptom that needs, as it were, to be explained away, and eversion may be due to a simple contusion. It is important, therefore, that the exact nature and extent of the rotation should be determined, and the sources of error are that an eversion which is only apparent may be thought to be real, and that it may be purely passive and accidental, the limb taking and keeping the inverted position quite as readily.

In order to estimate the degree and persistence of the eversion the patient should be placed flat upon his back with the thigh and leg extended. A comparison with the other foot will then show the degree of the eversion, and gentle efforts to rotate the limb will show to what extent and in what manner the movements are restricted.

Shortening of the limb is produced either by alteration of the angle between the shaft and the neck or by overriding, and may vary in extent from a small fraction of an inch to two, three, or even four inches. It may be present and at its maximum immediately after the accident, or it may be absent at first and appear gradually or suddenly after the lapse of a few hours or days, or may increase gradually, or suddenly. It is usually held that when the fracture is of the narrow part of the neck (intracapsular) the shortening is absent or slight at first, increases more or less gradually, and never exceeds one and a quarter inches, and gradual increase in the amount of shortening is claimed by some to be pathognomonic of this variety of fracture. These statements are true only as an expression of the average condition; in exceptional intracapsular cases the shortening may exceed this amount, and in fractures at the base of the neck it may increase gradually in the same manner.

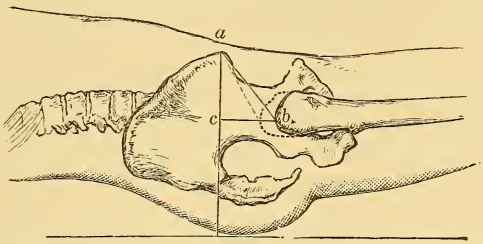
In measuring the limbs care must be taken to have them form the same angle with the pelvis, that each is in the same position of extension and abduction. If the injured limb cannot be brought parallel to the median line of the body the other must be abducted to the same degree. To insure this symmetry it is well to stretch a cord downward at right angles to and from the centre of another cord stretched between the two anterior superior iliac spines, and then to place the ankles at equal distances from it and as near to it as is convenient. The measurements are usually made between the anterior superior spine of the ilium and the external malleolus.

Another method of recognizing shortening and of measuring its extent is one recommended by Mr. Bryant, a modification of the former one of measuring the distance between the top of the trochanter and the crest of the ilium. The original method contained a possible source of error in the occasional displacement of the trochanter backwards which brings it into line with a higher part of the curved crest of the ilium, and thus

[1] Dict. Encyclopédique, Art. Cuisse, p. 239.

the elevation of the trochanter would not necessarily be accompanied by a diminution of the distance measured. Therefore, instead of measuring to the crest of the ilium, Mr. Bryant measures to the transverse vertical plane passing through the anterior superior spinous processes. Thus, in figure 278 *a c* represents the vertical plane passing through

Fig. 278.



Bryant's ilio femoral triangle, for diagnosis of fracture of the neck of the femur.

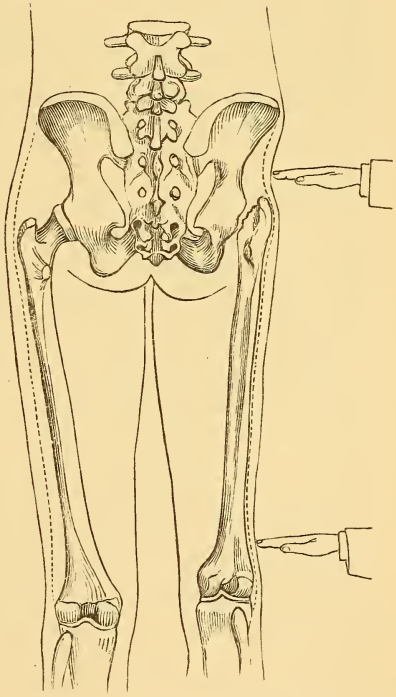
these processes, and *b* is the top of the great trochanter. In fracture of the neck with shortening *b* is brought nearer to *c*. The same care must be taken to have the limbs in symmetrical positions, and I have found it convenient to mark the vertical plane by placing a small stick or pencil upright beside the pelvis and in line with the processes and then to measure the distance between it and the trochanter.

Another, but less accurate method of recognizing the elevation of the trochanter is to find its position with reference to "Nélaton's line," the line taken by a cord stretched between the tuberosity of the ischium and the anterior superior spine of the ilium. Under normal conditions this line crosses the top of the trochanter when the thigh is slightly flexed on the pelvis.

Attention has been called by Dr. Allis to an effect of this shortening which can be easily recognized; the relaxation of the fascia lata between the ilium and the trochanter (fig. 279).

The shortening can sometimes be overcome, entirely or in great part, by gentle traction upon the limb combined with enough rotation inward to correct such eversion as

Fig. 279.



Method of recognizing the relaxation of the fascia lata after fracture of the neck of the femur.

may exist. I think the dread of separating impacted fragments by extension has been somewhat exaggerated. The penetration is transverse, and longitudinal traction that is not violent enough to cause much pain cannot do more than change the angle at the junction of the neck and shaft, it does not separate the fragments from each other. Rotatory movements communicated to the limb are more likely to do harm, as is also such lack of support as will allow the eversion and shortening to be increased.

Crepitation is occasionally perceived during the manipulation of the limb, either in extension or rotation, or on pressure behind the trochanter, but it is far from being a constant sign, either because of impaction or of splintering that leaves the pieces too loosely connected to produce it. The sign is one that should not be repeatedly sought for; in the cases that are really obscure it is highly improbable that it can be obtained, and in the others it is not needed. It was long ago noticed by Sabatier that those patients who had been persistently handled at the first examination showed the most severe inflammatory reaction and furnished most of the fatal cases.

Among other signs which may be present are enlargement of the great trochanter when it has been split or comminuted, change in its distance from the median line of the body, change in the centre of rotation of the limb, and change in the depressibility of the outer portion of Scarpa's space.

The enlargement of the trochanter in consequence of its having been split by the outer end of the neck is sometimes very marked and easily recognized when the soft parts are not swollen by grasping it between the thumb and fingers. In two cases reported by Stanley[1] a portion of the trochanter was broken off behind and drawn backward towards the sciatic notch, suggesting by its position and shape that it might be the dislocated head of the femur.

The distance between the outer face of the trochanter and the median line of the body may be increased or diminished, but the change is seldom very marked and is difficult of accurate determination. It is easier to prove that it ought to exist on theoretical grounds, than to recognize it if actually present. If the neck is driven into the trochanter the distance of the trochanter from the cotyloid cavity is diminished by the amount of the penetration; if, on the other hand, there is no penetration or crushing and the displacement is an angular one in the vertical plane, the bone being pushed up until the angle at the junction of the neck and shaft becomes a right angle, the distance is increased because the neck then stands directly out from the body instead of being inclined downward; and thirdly, in combinations of penetration and this angular displacement the two changes may neutralize each other in whole or in part.

In firmly impacted cases with but little shortening or eversion the trochanter sometimes appears exceptionally prominent, and, according to R. W. Smith, this prominence of the bone becomes very marked when the patient is supported in the upright position, but ordinarily the region is flattened and the trochanter appears to be sunken, displaced inward and backward.

[1] Med. Chirurg. Transactions, vol. xiii. p. 504.

Rotation of the trochanter upon a shorter radius than usual is another symptom found in the text-books but not at the bedside. Theoretically, if the lever upon which rotation is made is broken a new centre is formed at the seat of fracture or the radius is shortened by impaction. Nothing could be simpler or more accurate in theory, but in practice it is beset with difficulties that make it worthless as a sign, for it is recognizable only in cases where the diagnosis cannot be in doubt.

It is practically impossible to tell by pressing the finger against the outer face of the trochanter whether it rotates upon a long or a short axis, for the range of permissible motion is too limited to make it possible to recognize the sharpness of its curve. In cases of fracture with crushing of the neck and when the shaft lies unconnected with the remainder of the neck and the head, rotation of the limb takes place about the longitudinal axis of the femur, the centre of motion is within the shaft, not outside of it in the cotyloid cavity, and this can sometimes be recognized by pressing the finger against the *posterior* face of the trochanter and rotating the limb gently. Instead of rising from the finger the bone may be felt to slide over it.

The change in the depressibility of Scarpa's space is signalized by Hennequin[1] as a valuable diagnostic symptom. Under normal conditions the fingers can be pressed deeply into the limb in the outer portion of Scarpa's space, but when the neck of the femur is broken this depressibility is reduced in varying degrees, apparently by the angular displacement (with the apex directed forward) which takes place so commonly at the junction of the neck and shaft. The same condition was described by Laugier[2] as a sort of bony tumor to be felt on the outer side of the great vessels an inch or two below Poupart's ligament, slight pressure upon which was painful.

Diagnosis.—In most cases the existence of a fracture of the neck of the femur can be readily determined and sometimes its variety can also be easily recognized, but in others the main character of the injury is very obscure, and in a large proportion of cases it is simply impossible to say whether the fracture is intracapsular or extracapsular, of the narrow part of the neck or of the base of the neck. This difficulty is recognized by all practical surgeons and finds expression in some surgical works, although the text-books still preserve the distinction between the two forms and lay down rules for their recognition. Gosselin[3] says "a rigorous diagnosis between extra- and intra-capsular fractures is both impossible and useless." Mr. Bryant[4] says "the old division of intra- and extra-capsular fractures is as unscientific as it is impracticable;" and Agnew[5] "to recognize clearly a fracture through the neck of the femur, or to assert with positiveness that such a fracture is present is often a matter of no small difficulty, and occasionally one of impossibility;" and Hamilton[6] "the diagnosis between these two varieties of fracture is often impossible during the life of the patient."

[1] Des Fractures du Fémur, p. 700.
[2] Dict. Encyclopédique, art. Cuisse, p. 507.
[3] Clinique de la Charité, vol. i. p. 346.
[4] Loc. cit., p. 841.
[5] Loc. cit., vol. i. p. 941.
[6] Loc. cit., p. 425.

When the symptoms described above are clearly marked, when there is the history of a fall followed by complete loss of power in the limb, with shortening, eversion, crepitation, pain at the hip, and elevation of the trochanter, there can, of course, be no doubt,— the neck of the femur is broken. But when the limb is not entirely powerless, when the shortening and eversion are slight, perhaps even doubtful, when crepitation is not felt, when, in short, there is no single positive sign, the only course is to withhold the judgment, and wait for time to make the diagnosis clear. If the injury is only a contusion the recovery will be prompt and not marred by lameness ; if it is a fracture the more positive signs may appear as the tenderness and swelling subside, shortening and eversion will probably become evident, the patient will be unable to bear his weight upon the limb for several weeks, and he will probably walk always with a limp.

The examination should be directed first to the history of the case, then to the functions of the limb, then to its attitude and length, the condition and height of the trochanter, and the depressibility of Scarpa's space. If any doubt then remains the limb may be gently rotated, in order to judge of the degree of eversion and of its mobility, to elicit crepitation, and, if desired, to estimate the radius of rotation.

A possible source of error in the existence of a former fracture, or of a deforming or dry arthritis, to which a fresh contusion has just been superadded, must be borne in mind when the history of the case is inquired into.

Dislocation is eliminated in case of eversion by noting the absence of the head of the femur from the pubic region. The only dislocation that is characterized by eversion and shortening is dislocation upon the pubes, and in it the head of the bone can be very readily felt. The exclusion of dislocation backward upon the ilium in case of fracture with inversion of the limb is more difficult. In dislocation the limb is more fixed, it is adducted and flexed, the head of the femur can be felt posteriorly, and its absence from the cotyloid cavity may be recognized by palpation. In fracture the inversion may give place to eversion after traction upon the limb.

Fracture of the acetabulum with penetration of the head of the femur into the pelvis has usually been mistaken for fracture of the neck of the femur. The means of diagnosis has been mentioned in the preceding chapter. The mistake is comparatively unimportant, since the treatment is the same in the two cases.

With reference to the differential diagnosis between intracapsular and extracapsular fractures, it can only be said that some of the latter can be positively recognized, as, for example, when the trochanter is comminuted, or the immediate shortening is very great, or when the bony mass can be felt plainly in Scarpa's space. An opinion may be formed in others according to the degree of the violence, the age of the patient, the disability, and the extent of the shortening, but it can never express more than a probability. It may be reasonably expected that after the lapse of ten or fifteen days the swelling will have so far diminished that a close examination of the trochanteric region can be made, and then the differential diagnosis may be possible, because in fractures at the base

of the neck this region becomes enlarged and hardened by the formation of an external callus and the infiltration of the soft parts, while if the fracture is within the capsule this change does not take place.

Prognosis.—In this must be considered the immediate danger to the life of the patient created by the accident, and the remoter influence upon the functions of the limb. Of the 60 cases collected by R. W. Smith 26 terminated fatally within the first month and 4 within the second month. It must not be thought that these figures represent the average mortality of the injury, for his collection is only of cases that had furnished specimens, but they will serve to call attention to the actual danger that does exist, and to the probability that death will be caused promptly if at all.

The promptly fatal cases present two principal forms; in one the primary inflammatory reaction is sharp, a high fever sets in, the patient becomes delirious and dies within a few days, or pneumonia is developed soon after the accident and proves fatal. In the other form the patient's strength fails rapidly without much inflammatory reaction from the injury, and he dies cachectic, usually with an intercurrent pneumonia. It is possible that fat embolism, especially of the lungs, may be an important factor in producing this result. In other cases death follows an attack of traumatic delirium or an intercurrent bronchitis, or is the apparent result of marasmus due to prolonged confinement to the bed and constant pain.

The injurious effect of confinement to the bed and of pain has been clearly demonstrated by the diminution of mortality that has followed the abandonment of treatment by inelastic extension and by strict and prolonged confinement to one position. Gosselin has called especial attention to this fact, and attributes the change in treatment to the influence of the opinion that union was not to be expected after intracapsular fracture, and that, therefore, it was useless to make extension, and to keep the patient in bed after the second or third week. He adds that in thirty years of hospital practice, 1840 to 1870, he had seen only one case of death within a fortnight after the accident. The influence of age upon the prognosis is very well marked, the older the patient the greater the probability of a fatal termination within a few weeks or months, and the greater also, it is believed, the probability that the fracture is intracapsular, and the disability consequently greater and more permanent.

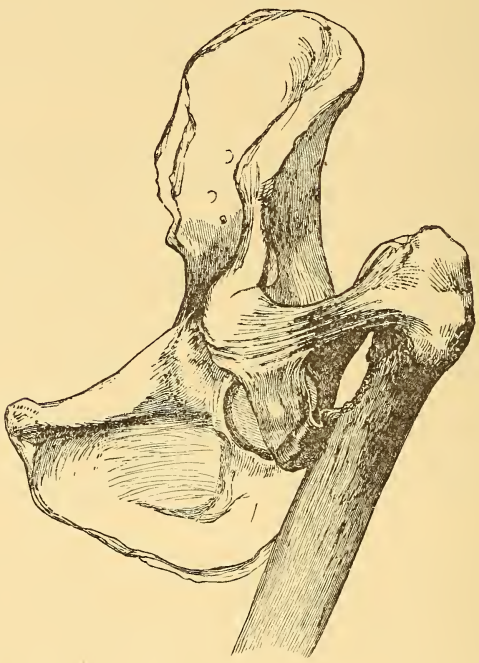
The inflammatory reaction is due in part to the arthritis set up by the injury, and this arthritis increases not only the immediate danger to life but also the subsequent disability in case of survival by the changes which it effects in the joint. This latter is always to be anticipated in a greater or less degree. The patient should be informed that even if union follows and the limb becomes useful, it will remain shortened and everted, and that the joint may long be stiff and painful. In fractures at the base of the neck, with or without impaction or comminution, union usually takes place promptly, even in advanced age, and the limb may become very useful, as in the following case.

A woman who said she was "going on 80 years old," and who looked as if she was at least 70 years old, an inmate of the Almshouse, was

pushed down by another woman in May, 1878, and broke the neck of the left femur. I found eversion, shortening of $1\frac{1}{2}$ inches, and an extensive ecchymosis covering the upper anterior, outer, and posterior portion of the thigh. The only treatment was rest in bed with the limb steadied and supported by cushions. She was not transferred to the hospital ward, and I soon lost sight of her. The following autumn I recognized her walking about the grounds with the aid only of a cane, and in the following February, I went to her ward and asked for her. She came walking forward briskly but with a marked limp. There was still marked eversion, and the same shortening; the trochanter rose more than an inch above Nélaton's line and was not enlarged. There was no complaint of pain.

What the proportion of useful limbs after fracture is, I cannot say; Mr. Bryant[1] "says that of thirty consecutive cases averaging 74 years in age treated by him in Guy's Hospital, all were discharged with useful limbs." So far as my observation goes this result is far better than that usually obtained in hospital or private practice.

Fig. 280.



Ununited fracture of the neck of the femur, showing the hypertrophied outer fasciculus of the Y-ligament supporting the weight of the body in walking. (Bigelow.)

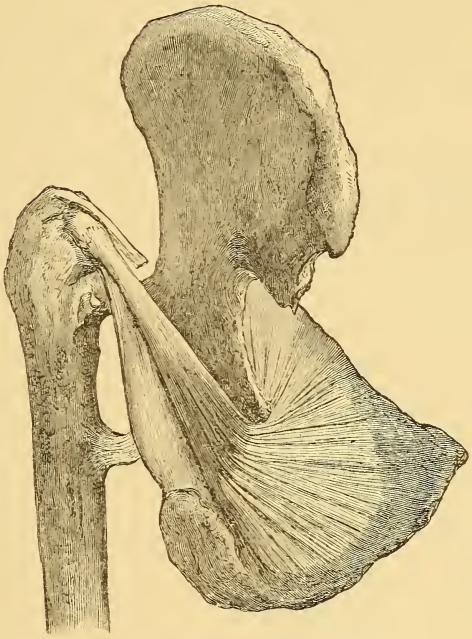
In the more unfavorable cases, especially those of fracture within the joint and without union, the patient may remain completely bedridden or able only to change from the bed to a chair, or to take a few steps

[1] Lancet, 1880, i. p. 160.

with the aid of a crutch or a nurse. Pain is common and the limb becomes much atrophied.

Failure of union after fracture within the joint does not necessarily cause complete disability. An instance of recovery with pseudarthrosis and good use of the limb has been quoted above from Gosselin. Figures 280 and 281 are taken from one of Prof. Bigelow's specimens, and show

Fig. 281.



The same, seen from behind, showing the tense obturator tendon and the hypertrophied inferior gemellus. (Bigelow.)

how the weight of the body can be supported by the anterior fasciculus of the Y-ligament in front of the femur, and the obturator internus behind after ununited fracture of the neck.

Treatment.—The attainment of the ideal object of treatment, restoration of form and function, is not to be expected; the small size of the upper fragment, the destruction of tissue by crushing, and the permanent change of the relations of the parts by impaction prevent the restoration of form, while the proximity or the involvement of the joint, combined as it usually is with advanced age, insures limitation of the functions even after complete consolidation.

The extent also to which attempts to reduce the displacement may be carried with propriety is limited. The same reasons which make it undesirable in many cases to attempt to carry the diagnosis beyond the recognition of the simple fact that there is fracture of the neck of the bone forbid attempts to overcome shortening and eversion. In view of the age of the patient, the severity of the injury, the probability of the

limitation of function in any case, the principal aim in treatment should be to keep the inflammatory reaction within the narrowest limits and to secure union at the earliest possible moment even if in a faulty position. The disability due to displacement may easily be less and of less importance than that due to a severe and prolonged arthritis excited or increased by the measures employed to overcome the displacement. Furthermore, in many cases the measures are not likely to be efficient. In fracture with impaction no traction that can be safely borne by the patient is likely to be sufficient to overcome the shortening, and in the common form of fracture, fracture at the base of the neck with crushing posteriorly and angular displacement in the direction of outward rotation of the limb, the eversion cannot be corrected without forcible manipulation, because when the inversion that is intended to correct it is kept within proper limits the motion takes place in the joint and not at the seat of the fracture, and the angular displacement, therefore, persists. And if the effort should succeed, if the angular displacement should be overcome, its probable effect would be to open a gap behind corresponding to the tissue that had been crushed, which would have to be filled by granulation, and which would certainly delay and perhaps prevent consolidation.

The treatment must be directed mainly to immobilize the limb, and the extension that is made should be with the view to aid immobilization and to prevent additional shortening rather than to overcome such shortening as may exist, and this immobilization and extension should be kept up until consolidation has been obtained, in fractures at the base, and until the character of the fracture, when within the joint, has become evident, and failure of union certain, or until the condition of the patient renders removal from bed and change of position absolutely necessary. The first consideration is to keep the patient alive, the second to obtain union, the third to get union in a good position.

It is not difficult to meet the indications, or, rather, simple measures will meet them sufficiently well. Prof. Bigelow says that he has obtained as good results, even in bad cases, from a flat bed with a moderate weight attached to the limb for extension, and a broad band about the hips to steady the parts, and a cushion under the broken limb to prevent its eversion as from more complicated apparatus, and most surgeons have probably had a similar experience. The simplest treatment is to make extension by weight by means of strips of adhesive plaster attached to the limb in the manner described in Chapter VIII., and to prevent eversion either by Volkmann's sliding foot rest (p. 182), or a long side splint as after fracture of the shaft, or by pads or cushions. The bed should be firm, not soft or springy.

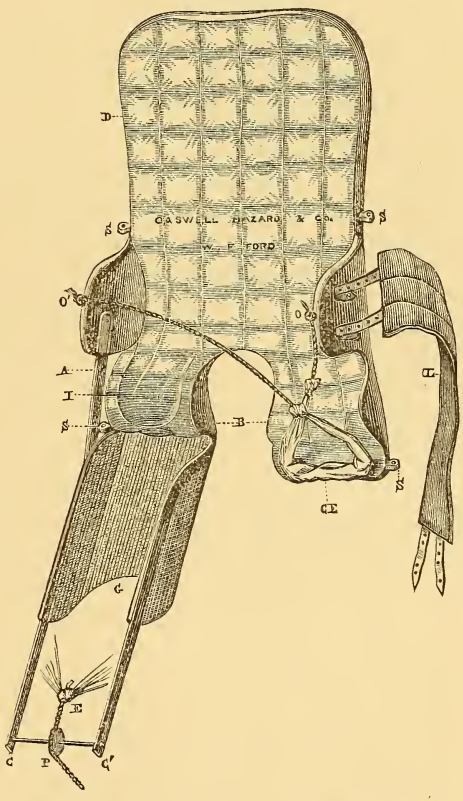
Dr. Hamilton uses extension by weight and his long side splint. Mr. Bryant, whose remarkable series of thirty consecutive cases averaging 74 years of age discharged with useful limbs has been mentioned, uses the double splint bracketed at the points corresponding to the trochanters (page 183) and makes extension by an India-rubber cord instead of a weight.

Bonnet's wire cuirass of full size supporting the head, trunk, and both legs has been used occasionally and has advantages that may at times

be useful. Extension can be readily applied by means of adhesive plaster, and counter-extension by a perineal band or by elevation of the foot of the bed as usual. It allows the patient to be moved and cleaned more readily than when he is lying in bed. It has been suggested that the various splints used in hip-joint disease are applicable also to the treatment of fracture; their only advantage would be that they might make it easier to move the patient in bed or from the bed to a chair or sofa, or, later in the case, to get about on crutches.

Hennequin advises that the limb should be kept abducted in order to relax the gluteal muscles and thus avoid their influence in causing shortening; it seems probable that this advantage would be neutralized by the greater tension which the position would cause in the adductors. A modification which he suggests of Bonnet's cuirass is shown in fig. 282 and seems to possess some advantages. The thigh rests in the grooved splint, the foot and leg are wrapped in an immovable cotton dressing extending above the knee and rest on a chair beside the bed, the knee being partly flexed, and extension is made by a weight attached to a bandage about the upper portion of the leg. Counter-extension is provided partly by the weight of the body, partly by a depression in which the buttocks rest, and partly by a perineal band. I should prefer extension by weight in the usual manner to this arrangement which requires the leg to be kept outside the bed, although patients with fracture of the shaft whom I have seen treated by Hennequin with a similar apparatus made no complaint of the position. The abduction can be easily got by placing the patient obliquely in the bed.

Fig. 282.



Hennequin's splint for fracture of the neck of the femur.

In a few cases of *painful pseudarthrosis* operative attempts to relieve have been undertaken, either to secure union or to remove the head of the bone. The first of the kind was by Langenbeck[1] between 1850 and 1860; he exposed the trochanter major and passed a silvered drill

[1] Deutsche Gesellschaft für Chirurgie, vol. vii. 1878, p. 92.

through it into the upper fragment so that it held them together. The patient was an old woman with an oblique fracture of the neck almost entirely extra-capsular which had remained ununited and very painful. The joint became inflamed, hospital gangrene attacked the wound, and the patient died. In Lister's case the patient survived, but the operation secured only fibrous union. The case is briefly referred to by MacCormac,[1] but no details are given beyond the fact that the bones were not pegged together.

Konig[2] was successful in 1875 by an operation similar to Langenbeck's. The patient was young and the operation was done antiseptically. A small incision was made down to the trochanter and a long metal drill passed through it into the neck, or at least in its direction. It is not stated whether or not the drill was left in place to hold the fragments together.

It is said to be very difficult to keep the head of the bone steady during the boring and to pierce it at the proper point. Trendelenburg[3] has proposed that the fracture should be exposed by an incision directly over it, the broken surface of the lower fragment exposed by extreme adduction of the limb, and the trochanter bored from within outward. Then the drill is removed, the limb straightened, the drill reinserted from the outer side and driven into the head, guided by a finger in the wound. A silver screw would then be used to fix the fragments together, the wound closed, suitable provision having been made for drainage, and the screw removed after a fortnight.

Dr. Howe[4] removed the head of the femur nine months after fracture of the neck, union having failed. The patient was a woman, 62 years old, she recovered from the operation, but the limb remained completely useless. Apparently there was no active process going on at the seat of fracture at the time of the operation, the neck was almost entirely absorbed, and the joint contained about a drachm of inspissated pus.

B. Fracture through the Great Trochanter and Neck.—Since the publication of Sir Astley Cooper's work on Fractures it has become the custom to describe this variety of fracture separately, and a certain degree of vagueness or indefiniteness in the first description has been preserved in most of the subsequent ones.

The class may be defined as composed of those fractures in which the line of fracture begins on the under surface of the neck at or near its junction with the shaft and passes obliquely upward and outward to the outer surface of the trochanter below its summit, dividing the bone into two parts, the upper one of which is formed by the head and neck and upper part of the trochanter.

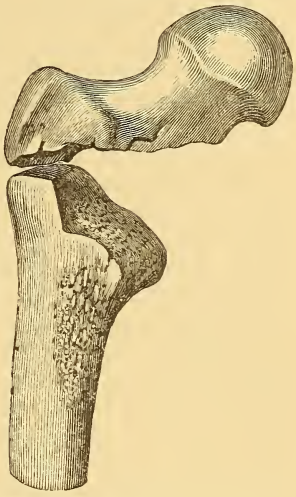
The recorded cases in which the character of the injury was shown by autopsy or made reasonably certain by the symptoms are few in number. In the first, seen by Cooper while a student, bony union took place, death was caused by a fever shortly afterwards, and the fracture,

[1] Antiseptic Surgery, pp. 197 and 200.
[2] Deutsche Gesellschaft für Chirurgie, vol. vii., 1878, p. 93.
[3] Idem, p. 91.
[4] N. Y. Medical Record, 1878, vol. xiv. p. 394.

so far as can be learned from the plate representing the specimen and the brief description, passed through or just below the lesser trochanter and ran parallel to the spiral line.

Another case described by R. W. Smith[1] as an extracapsular fracture (fig. 283). The details are scanty. The patient was 70 years old, and died on the fifth day. The limb was everted and shortened 1½ inches.

Fig. 283.



Fracture through the great trochanter. (R. W. Smith.)

Of the four additional cases given by Cooper only one can be accepted; in two the diagnosis remains obscure, and in the remaining one, which is quoted from Stanley (*Med. Chir. Transactions*, vol. xiii. p. 504), the fracture seems to me to have been the common fracture at the base of the neck with some splintering of the trochanter and displacement of the upper portion of this part. The error in interpretation, which has been followed by others, is due to the deficient description which says "the fracture extends obliquely through the trochanter major and through the basis of the neck into the shaft of the femur;" the accompanying plate shows a displacement of the upper and posterior portion of the trochanter with reference to the remaining portion that seems incompatible with the theory that it is unbrokenly continuous with the neck. A second and similar case, described in almost the same terms by Stanley in the same paper and with the same title, fracture of the trochanter major, is placed by Sir Astley in his chapter on fracture of the epiphysis of the trochanter. The point in each case which attracted Stanley's attention and which alone, in my opinion, distinguishes them from the ordinary fracture, is the free separation of a large upper fragment of the trochanter, in addition to the fracture of the neck, and its displacement. Similar cases have been reported by Michon[2] and Mercier[3] and quoted by Malgaigne as extra-capsular fractures. Mercier's case was thought to be a dislocation.

The symptoms mentioned in Smith's case are simply eversion and shortening of 1½ inches, and in Sir Astley's first case simply eversion. In the other in which the diagnosis appears reasonably certain there was slight shortening, the trochanter was drawn forward and could be felt considerably separated from that portion which remained connected with the neck of the bone; the foot was turned outward, the patient could not sit, and the least attempt to rise caused great pain.

The distinction from fracture of the neck would have to be made by recognition of the fact that the upper portion of the trochanter remained

[1] Loc. cit., Case 43.
[2] Bull. de la Société Anatomique, 1835, p. 37.
[3] Gazette Médicale, 1835, p. 564, Obs. 3.

connected with the neck, did not move with the lower fragment, and was not displaced backward as in Stanley's two cases.

In two of these three cases the patients recovered with a useful limb; one was able to walk freely in about a year, the leg remaining everted and shortened nearly an inch; another died of an intercurrent fever as he was about to leave the hospital, there was very little deformity, only some eversion of the foot, and he walked well; in the remaining case, Smith's, the patient died on the fifth day.

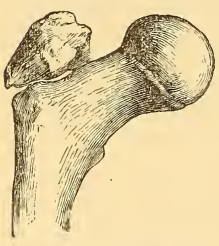
The treatment should not differ from that of fracture of the neck: extension to overcome or prevent shortening, a side splint or Volkmann's foot-rest to prevent eversion, and cushions to support the thigh.

C. Fracture of the Great Trochanter. Separation of the Epiphysis.—Cases of this kind verified by post-mortem examination are rare, and those in which the diagnosis has been made upon the symptoms have been differently interpreted by the different authors. The cases verified by direct examination are the following.

Aston Key[1] saw a girl 16 years old, who had fallen in the street and struck the trochanter against the curbstone. She rose and walked home without much pain or difficulty, but five days afterwards was admitted to Guy's Hospital on account of pain felt on the inner side of the thigh. The limb was everted and appeared to be half an inch longer than the other. Passive motion was possible in all directions, but abduction was painful. She had perfect command over all the muscles except the internal rotators. No crepitus or displacement, and no swelling. She had a high fever and died nine days after the accident.

The trochanter was found to be detached from the body and neck, but without rupture of the tendons attached to its outer side, and these acted as a hinge and allowed the fragment to move only upward and downward. Fig. 284 represents this specimen which is preserved in Guy's Hospital Museum.

Fig. 284.



Fracture or diastasis of the great trochanter. (Bryant.)

Waechter[2] saw a man 71 years old who fell while walking, struck upon his left hip, rose and walked home, and sought admission to the hospital a week later. There was no shortening, no sign of contusion; passive motion was painless, except outward rotation, and there was no crepitation. The hip became tender, and the limb took the position of flexion, adduction, and inward rotation; the patient grew feverish and died of hypostatic pneumonia four weeks after the accident.

The ligamentum teres was thickened and hyperæmic, but there was no effusion in the joint. The upper and inner portion of the trochanter was separated by a line of fracture which lay entirely outside the joint, beginning close by the upper edge of the insertion of the capsule, running downward and outward, and then up across the top of the trochanter.

[1] Cooper's Fractures and Dislocations, Case 100.
[2] Deutsche Zeitschrift für Chirurgie, vol. viii., 1877, p. 104.

The fragment, which was split into two pieces that were slightly movable on each other, was slightly displaced backward and inward, and the periosteum was torn in front, but not on the outer side. The tendons of the pyriformis, obturator internus, and gemelli, and the anterior fibres of the glutæus medius and upper fibres of the glutæus minimus remained attached to the fragment. There was no sign of repair, no extravasation of blood. A fissure three centimetres long in the shaft made the remaining half of the trochanter slightly movable.

Another case was reported by J. Clarke in the *Transactions of the Medical Society of Calcutta*;[1] a man, thirty-two years old, fell while running and struck heavily on the left hip and thigh. He walked home, a short distance, with help. There was no deformity, no crepitus; some swelling and contusion over the trochanter; and any attempt to rotate the limb inward caused extreme pain. He died on the eighth day of delirium tremens.

The trochanter was found to be crushed and shattered, several pieces entirely detached, and fissures extending deeply into the shaft.

A case was reported by McCarthy[2] to the Pathological Society, and is printed in the *Transactions* as "a traumatic separation of the trochanteric epiphysis," similar to Aston Key's quoted above. The patient was a girl, eight years old, who, when brought to the hospital, was considered too ill to be examined, and died a few hours afterwards. The history was that she had never had any illness previous to a fall upon the left side a week before while playing. A day or two later a lump was noticed on the left hip, and the child was kept in bed in consequence. A few days afterwards her breathing became so difficult that she was brought to the hospital, walking the distance, half a mile, and not complaining of pain.

The autopsy showed "pyæmic pericarditis, pleurisy, and pneumonia; a large extra-peritoneal abscess in the pelvis connecting along the tendon of the pyriformis with another around the neck of the left femur. The trochanteric epiphysis was completely detached from the shaft, but held in position by tendinous attachments and the reflections of the capsule.

The cases in which the diagnosis was not verified by direct examination are one under the care of Poland, quoted and pictured by Bryant (loc. cit., p. 846), and one reported by Sir Astley Cooper,[3] as fracture through the trochanter, but which, as Malgaigne points out, was more probably of this kind. Bryant refers also to a case reported in the *Canada Medical and Surgical Journal*, Nov. 1875, and Dr. Hamilton also reported a case as such, but now[4] doubts the correctness of his diagnosis.

Cooper's patient recovered after a tedious illness, and had good use of the limb. In Hamilton's, displacement upward of the trochanter persisted, and the patient was able to walk with only a slight halt.

The diagnosis would have to be made, during life, on the history of direct violence received upon the trochanter, the absence of symptoms

[1] Abstract in Am. Journal Med. Sciences, vol. xix., 1836, p. 181.
[2] Trans. of Pathological Society of London, vol. xxv., 1874, p. 200.
[3] Loc. cit., Case 96.
[4] Loc. cit., p. 429.

of fracture of the neck or of the shaft, localized pain, and possibly displacement of a portion of the trochanter.

Cooper treated his case with a bandage drawn tightly about the hips, so as to press the fragment downward and inward. In view of the tendency of the attached muscles to draw the fragment upward and backward, it is probable that union would be favored by keeping the limb abducted and rotated outward.

Agnew (loc. cit., p. 945) gives a figure of a specimen in his own possession, but adds no details of the case. He says only "there was present a considerable amount of granular callus around the circumference of the fracture, though there was none between the fragments."

2. Fractures of the Shaft of the Femur.

In this division will be included fractures just below the lesser trochanter, which are sometimes described separately under the title of subtrochanteric; fractures just above the condyles will be described in the section on fractures at the lower end of the femur.

The causes of fracture are direct and indirect violence and muscular action. Examples of the latter have been quoted in Chapter IV.; an additional one, which may deserve mention as probably the earliest on record, although hardly typical, is quoted by Pouteau;[1] a lad seventeen years old, while standing on the deck of a vessel which was rolling heavily, put out his right foot suddenly to save himself from falling; he uttered a loud cry, and his right thigh was found to have been fractured with displacement.

A case of fracture by convulsive muscular contraction, in a patient whose femur had been weakened by disease and the formation of a medullary abscess, is reported in the *Lancet* for Aug. 23, 1879, p. 279. The patient was forty years old, and had long suffered from the effects of a kick upon the thigh by a horse, effects consisting in the formation of abscesses, the discharge of small pieces of bone, and spasm of the muscles. During a violent spasm the bone was heard to snap. The spasms continued to be frequent and painful, and the limb at last was amputated. The fracture was at the junction of the lower and middle thirds, and was deeply serrated; the medullary canal was much dilated for about two inches and the cortex thinned, but there was no sequestrum. Dr. Agnew[2] refers briefly to two cases, one, under his own care, caused by the effort to avoid a fall after tripping, the other by turning in bed, and expresses the opinion that degeneration of the bone is a necessary preliminary to such a fracture.

Fractures by direct violence are caused by the passage of the wheel of a wagon, the kick of a horse, a fall across a rail, a blow by the pole of a wagon; fractures by indirect violence by a fall upon the knees or feet, and, very rarely, by torsion, as when the foot is held and the body turned.

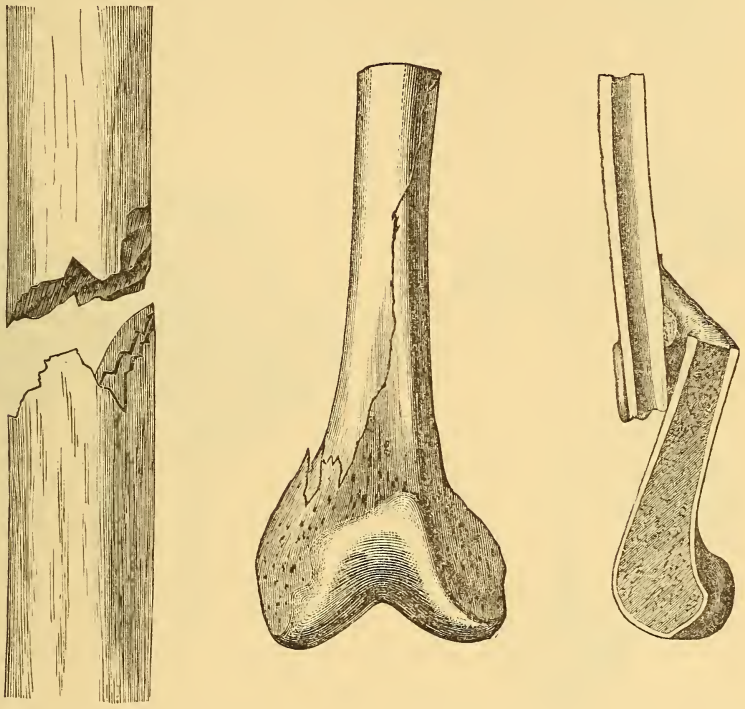
All the varieties of fracture that may occur in long bones are met with in the femur, but in the great majority of cases the fracture is oblique

[1] Œuvres Posthumes, 1783, vol. ii. p. 254.

[2] Loc. cit., p. 946.

and often extremely so, the obliquity usually corresponding to the normal curves of the bone; that is, in the middle part of the bone it runs from behind forward and downward, and in the upper third forward and outward. Transverse fracture is rare in adults, but common in children where the periosteum also remains in part untorn.

Fig. 285. Fig. 286. Fig. 287.



Toothed fracture of the femur. Oblique fracture of the femur. Transverse fracture of the femur. (Gurlt.)

The displacement is marked, and is the effect of the fracturing cause and of the contraction of the powerful muscles of the thigh; the lower fragment usually passes behind and to the inner side of the upper one and is sometimes rotated outwardly; in addition there is angular displacement, the angle usually being directed forward or forward and outward, but sometimes backward or inward.

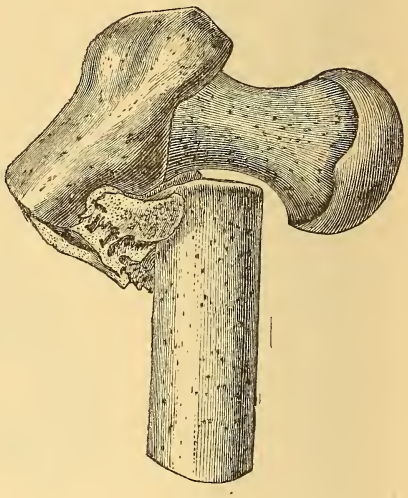
Inclination forward and outward of the lower end of the upper fragment after fracture in the upper third is the rule, and is mainly due to muscular action, to the contraction of the gluteal muscles and the psoas upon the upper fragment and of the adductors and the flexor of the leg upon the lower one. The tendency of the former is to tilt the upper fragment forward, outward, or in both directions; that of the latter is to draw the lower fragment up against the upper one, and this will produce

an angular displacement in any direction that is favored by the line of fracture. The fact that the displacement is sometimes backward or inward does not disprove the influence of the muscles attached to the upper fragment, as has been argued; the principal agency is the drawing upward of the lower fragment, and if the fragments are so related at the seat of fracture that the upper one is pushed in a different direction from that in which its muscles would draw it the latter must yield. In the extreme case figured by Sir Astley Cooper (fig. 288) it can be seen how great the angular displacement and at the same time the overriding can be under these circumstances. The angular displacement necessarily pro-

Fig. 288.

Fracture of the upper third of the femur; union with great displacement. (A. Cooper.)

Fig. 289.



Transverse fracture of the femur. (Gurlt.)

duces shortening, and this shortening varies according to the angle and, the angle being the same, according to the distance of the fracture below the neck of the bone. In the same specimen outward rotation of the lower fragment is also very marked. In transverse and toothed fractures the displacement may be lateral or angular or both, and if the lateral displacement is sufficient to free the fragments they may override, as in figure 289.

Fissures extending upward and downward from the seat of fracture are probably not infrequent, especially in gunshot fractures. A notable example has been quoted from Prof. Bigelow, page 496.

Double fractures have been observed, and, according to Malgaigne, there is a specimen of triple fracture in the Musée Dupuytren. Comminuted or splintered fractures are not uncommon, especially among fractures by direct violence, and the splinters may be large (fig. 290.)

The symptoms are pain, loss of function, abnormal mobility, deformity, and crepitation. As the bone is deeply placed under thick muscles irregularity in its outline cannot be recognized by the touch; angular displacement can often be readily recognized in thin patients by the eye, but the method of examination which renders the best service in this respect is the comparative measurement of the two limbs. The fixed points commonly used for this purpose are the anterior superior spinous process of the ilium and tip of the external malleolus; the rules for making these measurements and the precautions to be taken to guard against error have been given in Chapter V. and in the preceding section of this chapter, page 510; the capital point is to make sure that the two limbs form the same angle with the pelvis, and the best method of doing this is to stretch a tape across the abdomen from one anterior superior iliac spine to the other, and a second one at right angles to the first from its centre downward, and then to place the ankles at equal distances from the second line.

Fig. 290.

Fracture of the neck of the femur and of the shaft. A splinter, *a*, 5 inches long and nearly 1 inch wide, composed of the cortical layer, has been turned completely about its long axis and become united, with its original periosteal surface in contact with the other fragments. (Figured by Guilt from the Museum of the Royal College of Surgeons, England, No. 454.)

If the upper limit of the great trochanter can be distinctly made out the measurement may be made from it to the external malleolus; or instead of making the measurements the surgeon may simply note the difference in the positions of the internal malleoli as they lie side by side. Of course it is essential in the latter case that the limbs make the same angles with the pelvis. The shortening may vary from a small fraction of an inch to two, four, or even six inches.

Abnormal mobility may be recognized by placing the hand under the thigh at the suspected seat of fracture and gently lifting it, or by holding the upper portion of the thigh down with one hand and gently lifting the leg or moving it from side to side with the other, or by observing whether the great trochanter moves with the leg when the latter is gently rotated.

Usually the diagnosis can be made upon the pain, the powerlessness of the limb, the shortening, and the facility with which the shortening can be overcome by traction. The examination for abnormal mobility and crepitation should be made very gently, and should not be prolonged if the latter is not promptly obtained.

Extreme obliquity of the fracture, which is not uncommon, leads occasionally to a complication which may be very troublesome and may transform a simple fracture into a compound one, the penetration of the muscle and sometimes of the skin by the sharp end of the upper frag-

ment. Other complications are rare, the vessels and nerves not being in sufficiently close relations to be often injured. Laurent[1] found only two cases in which the artery had been injured; one was a fracture in the lower third caused by the kick of a horse, the other a secondary fracture after union with displacement.

A simple fracture without displacement, or suitably reduced, will usually consolidate in six or seven weeks sufficiently to allow the patient to get about on crutches, and he will be able to bear his weight safely upon the limb, and to discard the crutches in three or four weeks more. In exceptional cases the consolidation may be delayed, and it happens occasionally that a secondary fracture occurs soon after the patient first leaves his bed, usually in consequence of a fall. Gosselin, who has seen this accident happen on the 70th and 75th days, prefers to keep his patients in bed until the 80th or 90th day.

The effusion into the knee-joint which is observed so frequently in the course of fractures of the thigh has received particular attention since 1870, when Rouge, of Lausanne, first wrote concerning it. Among those who have studied it most carefully are Gosselin,[2] Berger,[3] Marjolin, Alison,[4] and Hennequin,[5] the two former attributing it to the passage of extravasated blood into the joint, the third and fourth to interference with the return venous circulation, and the last, in common with Verneuil and others, to an associated sprain. Others again have sought the cause of the effusions noted in the later periods of the case in the prolonged immobility and the extended position. An appreciable effusion makes its appearance in a majority of the cases within the first three days following the injury; it is most prompt in children, and when the fracture is in the lower third, and is more common after fracture by indirect than after fracture by direct violence. It disappears promptly in children, more slowly in adults, and may persist for years.

Prognosis.—Any fracture of the femur is a serious injury, to this extent, that its proper treatment makes confinement to the bed for several weeks desirable, that it will make it difficult for a long time for the patient to get about even with crutches, and that it may lead to shortening of the limb, even if not to a persistent limp.

Most authorities assert that an oblique fracture of the shaft of the femur cannot be cured without some permanent shortening. Since the time of Desault the possibility of a better result has been claimed by different surgeons, and for different dressings, but no method has yet won a general acceptance of its claim. While there is no reason to doubt the possibility of a union without shortening, and while I believe such union has been obtained in some cases, I do not believe there is any method of treatment which can be depended upon to secure it in any given case, for it can never be known in advance whether or not the patient will be able to support the traction and pressure necessary to success. Some surgeons have claimed an actual elongation of the limb

[1] Des Anévrysmes compliquant les Fractures. Thèse de Paris, 1874.
[2] Clinique de l'Hôpital de la Charité. [3] Thèse de Paris, 1873.
[4] Thèse de Paris.
[5] Loc. cit., p. 78. (See also the discussions in the Bulletins de la Société de Chirurgie, 1878, pp. 6 and 336.)

by the use of continuous extension. Although a certain doubt is thrown over such assertions by the acknowledged difficulty of making accurate measurements, and by the possibility of a previously existing inequality in the length of the limbs, the occurrence is not impossible, however improbable it may be thought.

The persistence of some shortening, even an inch, does not necessarily cause the patient to limp, since it is readily compensated for by an inclination of the pelvis. The rigidity in the knee is likely to persist for a length of time that is greater as the patient is older and of a rheumatic habit.

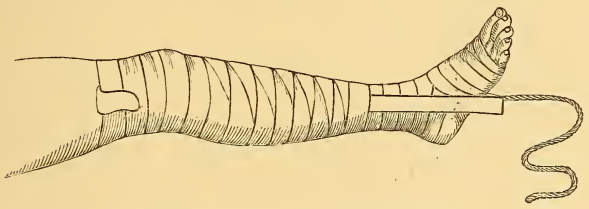
The prognosis in compound fractures is particularly grave when the injury has been produced by direct violence; and in a fracture of both thighs, particularly if either is compound, the shock is usually so great as to put the patient's life in serious danger.

Treatment.—The different methods and apparatus that have been employed in the treatment of fractures of the thigh are very numerous, and most of them have been abandoned in favor of a few whose merits and superiority have won general recognition.

Buck's Extension Apparatus.—Prominent among them is the method of continuous extension with which the name of the late Dr. Gurdon Buck is associated. It is simple in construction, easy of application, causes no pain to the patient, and allows thorough examination of the limb at all times. It is the method which I use habitually, and I believe it to be the one in most general use in New York.

The details of its application have been described in the chapter on Treatment, page 181. Figure 291 shows how the strips of adhesive

Fig. 291.

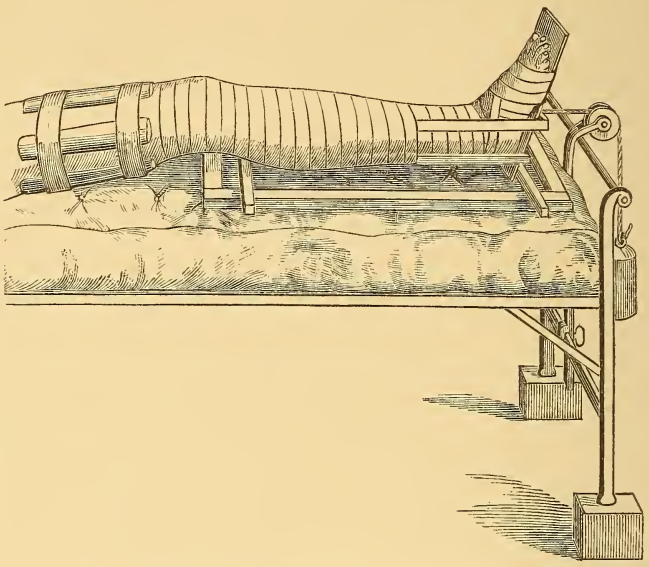


Adhesive plaster applied for extension.

plaster are made fast, and figure 292 shows the limb resting upon a Volkmann's sliding rest, with the weight and the short coaptation splints. A perineal band for counter-extension is unnecessary if the foot of the bed is raised about six inches. When Volkmann's rest is used a thin cushion or folded sheet should be placed under the thigh to support it, and it is usually desirable to make special pressure with cushions or sand bags below and on the outer side of the thigh to correct any angular displacement or oppose the tendency of the upper fragment to rotate outwardly. This latter tendency should be especially watched for and opposed; the patients often show a strong inclination to lie partly on the injured side, instead of squarely on the back, and when they do so the pelvis sinks on that side and rotates the upper fragment outward, while

the lower fragment and foot are kept stationary by the dressings. Even when the patient lies flat on his back the trochanter can sometimes be seen to occupy a more posterior position than the one on the other side,

Fig. 292.



Volkmann's sliding rest for fractures of the thigh.

to be rotated outward, and it must either be held up on cushions or the foot and lower segment must be rotated in the same direction by raising the inner side of the sliding rest.

Besides its simplicity of construction the method has the other merit of allowing a certain liberty of motion and choice of position to the patient which make his confinement less irksome, less dangerous, and less likely to cause bedsores. It is unnecessary to keep his head and shoulders low, he can sit up in the bed, resting on pillows, and can move himself up and down with a freedom quite as great as that furnished by a suspended splint. Indeed, it is rather startling to see the apparent recklessness with which a patient will raise himself upon his elbows and draw himself rapidly up in the bed. The sliding-rest and the weight and pulley furnish a valuable combination of solidity and freedom.

Care should be taken to carry the adhesive straps and the roller bandage which secures them several inches above the knee, if the position of the fracture permits, in order to take some of the strain of the weight off the ligaments of that joint; and when the fracture has been above the middle of the shaft I have sometimes reapplied the strips after the third week so that they would adhere only to the lower part of the thigh, and would leave the leg free for passive motion at the knee.

The roller bandage which secures the strips of adhesive plaster is sometimes coated with silicate of soda to give it a smooth finish and make it more solid, but the practice seems to me to be undesirable be-

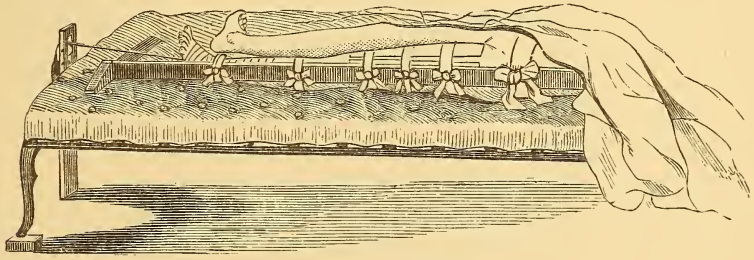
cause of the unpleasant reaction of the impervious coating upon the skin. The same objection applies to plaster of Paris.

The pulley should be in the line of the axis of the limb or slightly above it, and the end should be long enough to allow the limb to be moved up and down in the bed for the distance of a foot or eighteen inches. If a pulley cannot be obtained one can be extemporized out of a spool and a stout iron rod or wire. The weight must vary according to circumstances ; fifteen or twenty pounds are usually required at first for a healthy stout adult, and it may be reduced one-half after the third week.

The coaptation splints, three or four in number, should be ten or twelve inches long and two inches wide, suitably padded, and made fast with straps or pieces of bandage that can be tightened at will. A plaster of Paris casing, made with the ordinary plaster roller, and extending from the knee to the trochanter, is an excellent substitute for the wooden splints after the first or second week.

As soon as the abnormal mobility is lost the limb may be enveloped in plaster, and the patient allowed to go about on crutches. I think it is imprudent to make this change before all danger of the occurrence of shortening has passed, and as a test of this I remove the weight for a day or two ; if the limb does not shorten during this time I apply the plaster, if it does shorten I reapply the weight. The plaster dressing should include the leg and the pelvis, and need not be very heavy, since it is intended only to give additional support and to guard against accident. It should be kept on for two or three weeks and reapplied if on examination the union appears insufficient or tender. The danger to be guarded against in the later stages of treatment is that of secondary fracture, rupture of the callus, by a comparatively slight cause. It arises when the patient leaves his bed and continues for some time thereafter, even to the end of the third month, and it should be impressed strongly upon the patient, especially upon the young and active who chafe under the confinement and are anxious to prove to themselves that they are well. With such patients confinement to the bed and encasement in plaster should be prolonged beyond the usual time.

Fig. 293.



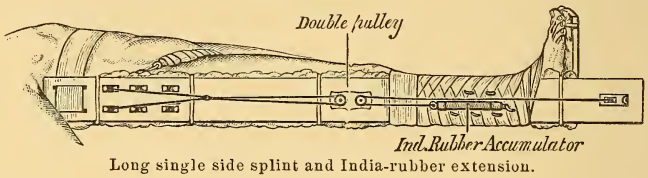
Long side splint. (Hamilton.)

Dr. Hamilton uses in addition to the weight a long side splint with a cross-bar at the foot (fig. 293) to give additional steadiness to the fragments and to prevent rotation. The sliding-rest, which is of later intro-

duction, meets the latter indication equally well and has advantages of its own. If it is thought desirable to give the fragments more support than the short coaptation splints supply, a moulded thigh-piece of plaster or pasteboard may be added.

Long side splint.—In the long side splint, single (fig. 294) or double (fig. 295), an India-rubber cord is substituted for the weight and pulley,

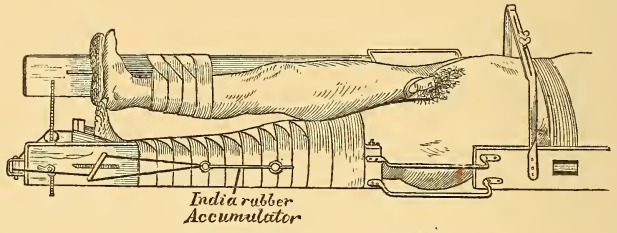
Fig. 294.



Long single side splint and India-rubber extension.

and the dressing is entirely independent of the bed. Counter-extension is made in the single splint by a perineal band, and in the double one by a brace for the foot on the uninjured side. The India-rubber which

Fig. 295.



Double side splint. (Cripp's.)

makes the extension is attached to the limb as in Buck's method by strips of adhesive plaster secured by a roller bandage.

The single splint must be long enough to reach from a few inches below the foot to the axilla, and is sometimes bracketed opposite the trochanter. After the adhesive strips have been applied the splint is placed against the outer side of the limb and body with a long, narrow, well-padded cushion between, and made fast at the upper end to the perineal band which must be well padded and fitted smoothly to the groin. Then extension is made upon the foot by an assistant to bring the limb down to its full length, and the cord is carried around the pulley at the bottom of the splint and made fast to the rubber. Finally, a body bandage is passed about the upper end of the splint and the chest.

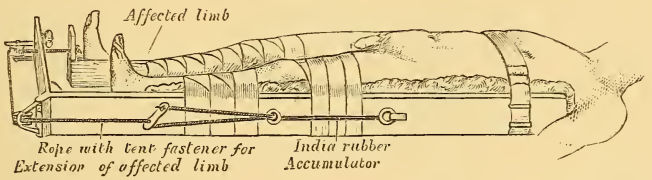
In the double splint the perineal band is gotten rid of by making the counter-extension through the opposite limb, and by raising the foot of the bed two or three inches. The apparatus is sufficiently well shown in figure 295 to render a detailed description unnecessary. Mr. Bryant speaks highly of this splint, saying that in 31 cases treated with it consecutively by him there was no shortening in 18, less than half an inch in 10, and in only 3 did it amount to an inch.

The disadvantages of this method, as compared with Buck's extension,

are in the use of the perineal band and in the more rigid confinement to one position in the bed. On the other hand it probably keeps the fragments steady.

Various attempts to do away with the perineal band by the substitution of other methods of making counter-extension have been made but have not gained much favor. Sir Wm. Ferguson applied "counter-extension from a strong stay of jean carefully fitted to the opposite thigh, from which a band extended in front and behind to the upper end of the splint." Mr. Campbell de Morgan places the long splint on the uninjured side for counter-extension, and makes the extension about a pulley placed on a crosspiece at the foot (fig. 296). Dr. Hodge prolonged the

Fig. 296.

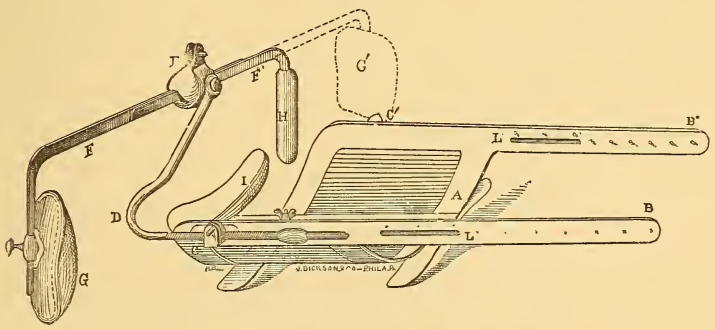


Campbell de Morgau's splint.

splint beyond the shoulder by means of a bent iron rod and made the counter-extension by strips of adhesive plaster fastened to the front and back of the chest.

Hennequin's splint, which seems to have become quite a favorite in France, consists of a gutter of wire gauze in which the thigh lies (fig. 297) with the knee bent and the foot resting on a support by the side

Fig. 297.



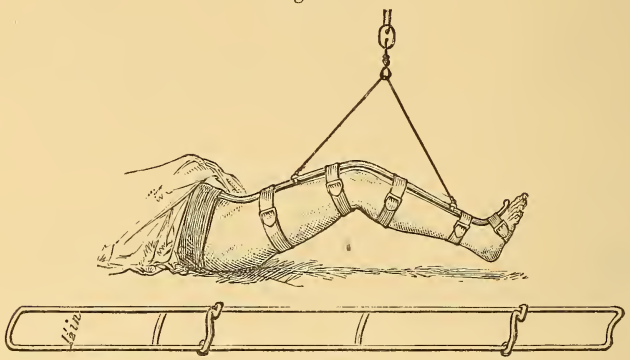
Hennequin's apparatus for fracture of the femur.

of the bed. Counter-extension is made by three pads attached to the upper end of the gutter. The lower one is in the form of a crescent, and takes its bearing against the ischium, the other two are attached to adjustable rods, G and H in the figure, and rest against the pubes and ilium. Extension is made by elastic bands fastened at one end to a padded leather band which buckles about the lower portion of the thigh and buttoned at the other to the ends of the side pieces of the gutter. A

second pair of elastic bands attached to the same bars make traction against the back of the upper part of the leg. The foot and leg are wrapped in cotton batting and the lower end of the gutter is swung from any convenient fixed point above the bed.

Anterior splint.—The suspended anterior splint introduced by Nathan R. Smith (fig. 298), and modified by Prof. Hodgen is highly esteemed

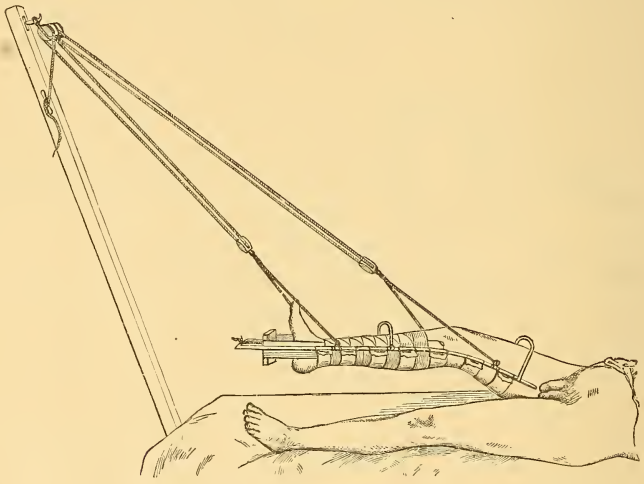
Fig. 298.



Nathan R. Smith's anterior splint.

by some surgeons, especially in the treatment of compound fractures. Extension is made by having the point of suspension beyond the foot, and counter-extension by the weight of the pelvis. Smith's splint is

Fig. 299.



Hodgen's splint.

made of parallel rods of iron wire bent to fit at the knee, ankle, and groin; it is placed along the front of the limb and made fast to it with a roller bandage or with strips of stout muslin or leather passing under the limb from one side to the other.

Hodgen's splint is rather stouter, and the bars pass beside the limb and beyond the sole of the foot instead of in front. It is secured to the limb by strips of adhesive plaster and a stirrup as in Buck's extension, the limb rests upon broad strips of bandage or straps passing under it from one side to the other, and the whole is suspended as shown in figure 299, which is said by Mr. Bryant to represent the manner in which it is used at Guy's Hospital.

The Plaster of Paris Dressing.—This form of the immovable dressing had a notable return to favor in this country between 1870 and 1875. It was introduced into Bellevue Hospital by Dr. Sands and Dr. McBurney, at that time his house-surgeon, and the extensive use that was subsequently made of it was largely due to the excellence of the results obtained with its aid in that hospital. The claims made for it were somewhat exaggerated and it is now used very much less than it was a few years ago. I have not seen a recent fracture of the thigh thus treated in Bellevue or the Presbyterian hospital in several years, and on inquiry of the surgeons of the New York, Roosevelt, and St. Luke's hospitals I learn that its use is equally restricted or abandoned in those institutions. Mr. Erichsen,[1] however, says he has treated many fractured thighs with this or the similar starch dressing "without confinement to the bed for more than three or four days, and without the slightest apparent shortening or deformity being left." A fracture of the thigh is, in my opinion, a sufficiently serious injury to make it worth the patient's while to remain in bed for a month, and the advantages to be obtained by getting him out of bed in the first week can seldom compensate for the risk it involves of producing an inferior result, perhaps a life-long deformity.

Fig. 300.

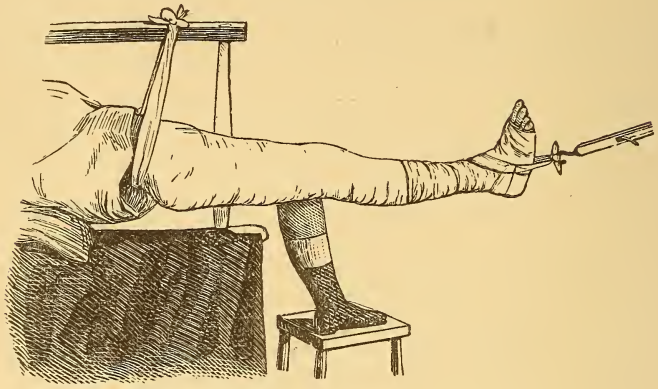
Plaster of Paris dressing; fracture of thigh. (Erichsen.)

The general details of the application of the bandage have been given on page 174; among the special ones are the following: The bandage may be first applied to the foot, ankle, and lower part of the leg and allowed to harden, then the patient's body is raised above the bed or table by a sling passed about his waist and attached to a support, counter-extension is provided for by a well greased perineal band or an upright rod made fast to the table and padded so that it will not chafe the perineum against which it rests, and then traction is made upon the foot. When the limb has been drawn down to its full length the remainder of the plaster dressing is applied, and is strengthened at the groin by a piece of blanket or similar loose meshed material soaked in plaster cream and laid over the anterior and outer aspects of the region. Extension must be kept up until the plaster has hardened. Anæsthesia may be used to diminish the resistance of the muscles or pressure made upon the femoral artery. If

[1] Science and Art of Surgery, Am. ed., 1873, vol. i. p. 376.

the patient is allowed to get up the limb should be supported by a sling passing under the sole and about the neck.

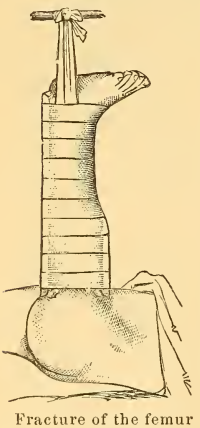
Fig. 301.



Fracture of the femur. Waiting for the plaster to set.

Fracture of the Thigh in Children.—Extension by weight and pulley is not satisfactory in these cases because of the restlessness of the patient, and the soiling of an immovable apparatus by the feces and urine will often make a change necessary. The practical difficulties in the way of the usual dressings have seemed so great that some of the most experienced surgeons, Paget and Callender,[1] have discarded them entirely and have treated many such fractures without splints, "the child being laid on a firm bed, with little or no head pillow, with the broken limb, after setting it, bent at the hip and knee and laid on its outer side." This practice may answer in some cases of transverse fracture without rupture of the periosteum, but I should not be willing to trust to it.

Fig. 302.



Fracture of the femur in a child, treated by vertical extension.

Mr. Bryant[2] recommends "that the injured limb of the child, together with the sound one, be flexed at a right angle with the pelvis, fixed with some light splint, and hoisted upwards to a cradle, hook, or bar above the bed. (Fig. 302.) By these means the weight of the body acts as a constant counter-extending force, the child can be well looked after for purposes of cleanliness, and a good result may be expected. At Guy's we have had excellent results from this practice." Lentze[3] reported a case treated in this manner on Schede's suggestion very satisfactorily. The child was 2½ years old and the thigh was broken between the middle and upper thirds; extension was made by strips of adhesive plaster attached in the usual manner, the cord was carried over a pulley immediately above the pelvis, and the weight, 4½ pounds, was

[1] St. Bartholomew's Hospital Reports, 1867, p. 385.
[2] Practice of Surgery, 3d Am. ed., p. 849.
[3] Berliner Klin. Wochenschrift, 1880, No. 52.

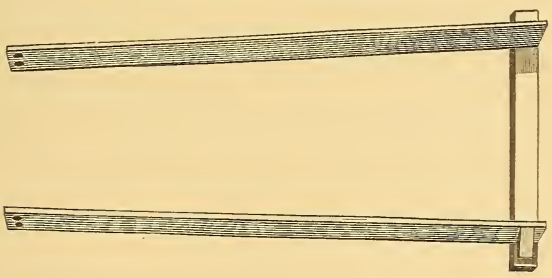
enough to make the pelvis, with a little aid from the hand, swing clear. The child appeared to be perfectly comfortable during the four weeks the position was maintained, and frequently sat upright in the bed, his body parallel to the limb. Lentze suggests that a cross-bar should be attached to the foot to slide between two pairs of vertical rods and prevent rotation.

Mögling[1] makes the apparatus independent of the bed, so that the child can be taken into the air. He lays the child on its back on a well-padded board to which a barrel hoop is fixed so as to be directly over the pelvis, and to this the foot is attached by an elastic cord. The child is also tied fast to the board.

It has been asserted that the confinement to this position is dangerous because likely to cause trouble in the lungs. Kümmell[2] has answered the objection by reporting the results of the treatment in forty cases, 12 under one year, 16 between one and two years old, and 12 more than two years old: 3 died, of causes independent of the fracture; in all the others the result was satisfactory. In one case the extension was kept up for 111 days, and in another for 104 days without causing the least trouble. An increase in the length of the limb, amounting to from one to two centimetres, which occurred not infrequently, disappeared under use.

Dr. Hamilton uses a double long side splint with a cross-bar at the lower end (fig. 303). The splints reach nearly to the axilla on each

Fig. 303.



Hamilton's splint for fracture of the femur in children.

side, and the limbs and body are made fast to them with a roller bandage. Coaptation splints, a perineal band, or elastic extension may be added if desired.

The wire cuirass used in disease, or after excision, of the hip-joint furnishes a convenient means for immobilizing the limb and making extension.

Gritti[3] published the results of the treatment of 38 cases of fracture of the thigh in children under the age of seven years by weight and pulley. The points of special interest are that in the great majority of cases the

[1] Centralblatt für Chirurgie, 1882, p. 292.
[2] Berliner Klin. Wochenschrift, 1882, No. 4.
[3] Centralblatt für Chirurgie, 1881, p. 155.

fracture had consolidated by the twentieth day, the minimum was eleven days in a child one year old, the maximum sixty days in a rachitic child.

For the treatment of compound fractures and failure of union the reader is referred to the chapters on those subjects.

3. Fractures at the Lower End of the Femur.

In this group are included fractures at or just above the base of the condyles, the supracondyloid fractures, intercondyloid fractures, separation of the lower epiphysis, and fracture of either condyle.

These fractures may be produced by indirect violence, as in a fall upon the feet or the knees, or by the fall of the body when the leg has become fixed by slipping into a hole or between the rounds of a ladder, or by direct violence as in the passage of the wheel of a wagon or in a blow received directly upon the part. The special importance of the fracture is found in the proximity or direct implication of the knee-joint and in the difficulty of exercising an efficient control over the comparatively small lower fragment.

A. Supracondyloid Fracture and Separation of the Epiphysis.—In this class are included fractures of the shaft lying within the lower four inches of the bone, fractures which are relatively more common in early life when compared with fractures of or between the condyles. The fracture is commonly produced by indirect violence, a fall upon the feet or knees, and in some cases by avulsion as above mentioned, the leg being fixed while the body is projected forward or to one side.

The fracture is usually oblique, and from above forward and downward, but the obliquity may be in any direction and may be so slight that the fracture is almost transverse. Quite a number of cases of traumatic separation of the epiphysis have been reported; one of them, seen by Chauvel[1] in 1872, is unique. It was produced in an attempt to straighten a knee that had become ankylosed in a faulty position in consequence of a tumor albus. An abscess formed and the patient died of pyæmia.

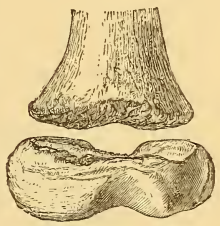
As a result of the usual obliquity in the direction of the line of fracture the fragments override, the upper one passing in front of the lower and its point sometimes engaging in the substance of the quadriceps muscle or its tendon or even perforating both it and the skin. Boyer maintained that the lower fragment turned upon its transverse axis so that its articular surface looked more or less directly forward, and its fractured surface backward, but this displacement has been shown to be rare. It exists in some cases; Trélat[2] reported one in 1854, Broca,[3] Follin, and Richet, each one in 1857, but usually the fragments remain nearly parallel to each other. When the fracture is oblique, backward and downward, and in some cases of transverse fracture or separation of the epiphysis, the lower fragment is displaced forward. In either case the

[1] Dict. Encyclopédique, Art. Cuisse, p. 233.
[2] Archives Générales de Méd., 1854, vol. ii. p. 78.
[3] Bull. de la Société de Chirurgie, vol. vii., 1857, p. 297.

popliteal vessels may be so pressed upon as to cause gangrene of the parts below. The tilting backward of the upper end of the lower fragment, when it occurs, is due to the contraction of the gastrocnemii, and the displacement is opposed by the adductor magnus. Malgaigne denied that this angular displacement ever occurred, but although Boyer overstated its frequency, and although the clinical proof claimed by so many, the presence of a hard mass in the popliteal space which is made less prominent by flexing the knee, is insufficient, yet its occasional occurrence has been demonstrated post mortem.

Separation of the epiphysis, which is theoretically possible until about the 25th year of life, has been observed at different ages between the moment of birth and the 16th year. Manquat[1] collected 106 cases, of which 20 were of the lower end of the femur. It has been produced by direct violence, but more commonly by traction upon the leg with torsion, or by hyper-extension of the knee as in Coural's[2] case, the first one reported with details, a boy 11 years old who engaged his leg in a hole and fell forward. Volkmann[3] calls attention to the facility with which this accident takes place when the hip-joint is diseased; he says he has produced the separation, at the lower end of the femur, three times in such cases by the traction made in applying a plaster dressing or the rotation in seeking for crepitus. In several cases it has been produced by the leg becoming engaged between the spokes of a wagon wheel in motion. In a few cases it has been caused intentionally to remedy a genu valgum, and once accidentally by Chauvel, as above mentioned, in an attempt to straighten a knee that had become fixed at a right angle in the course of a white swelling of that joint; the straightening was easily effected, but abscesses formed and the patient died of pyæmia. The autopsy verified the diagnosis. Some of the cases have been compound from the beginning, others have become so by suppuration at the seat of fracture and opening of the abscess. The diagnosis in the compound cases may be made by recognition of the cartilaginous layer on the surface of one of the fragments, usually the lower one; in the simple ones by the position and direction of the fracture and the age of the patient. It is possible that the growth of the limb may be checked in consequence.

Fig. 304.



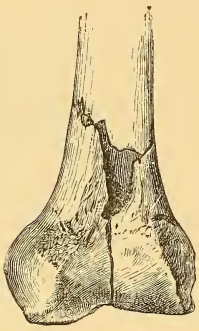
Separation of the lower ephiphysis of the femur. (Bryant.)

The diagnosis of supracondyloid fracture is not difficult. In addition to the usual signs of loss of power, pain, crepitation, and abnormal mobility we usually find a deformity which is characteristic, a dropping backward of the lower fragment and upper part of the leg, and a projection of the patella forward, especially of its upper end. In consequence of the overriding the patella is freely movable unless the tendon of the quadriceps is penetrated by the sharp end of the upper fragment and the patella fixed between it and the head of the tibia.

[1] Sur les décollements épiphysaires traumatiques. Thèse de Paris, 1877.
[2] Archives Générales de Méd., vol. ix., 1825, p. 337.
[3] Virchow's (Canstatt's) Jahresbericht, 1866, ii. p. 337.

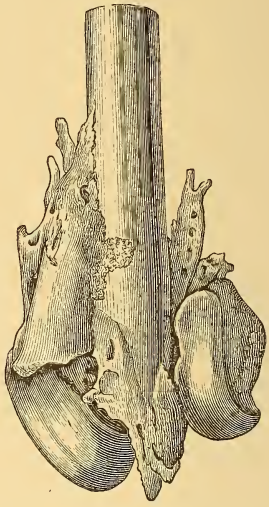
B. Intercondyloid Fractures (fig. 305).—In these fractures both condyles are separated from the shaft and from each other, the line being T- or Y-shaped. The fracture is sometimes classed as a supracondyloid fracture with splitting of the lower fragment, since that is thought to be the mode of production in most cases; the shaft is first broken and then the upper fragment penetrates and splits the lower (fig. 306). The claim that the fracture is caused by a violence transmitted

Fig. 305.



Intercondyloid fracture of the femur. (Bryant.)

Fig. 306.



Comminuted fracture of the femur, with splitting of the condyles.

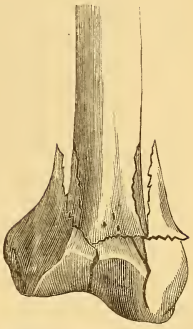
through the patella which acts as a wedge and splits off the condyles does not bear the test of experiment or harmonize with the fact that in a fall the blow is rarely received upon the patella. Trélat,[1] in the elaborate article in which it was first sought to give a detailed and full account of the fracture of the lower end of the femur, points out that in six cases of supracondyloid fracture the average age was 27½ years, while in thirteen cases of intercondyloid fracture it was 48½ years. The number of the cases seems to me too small to warrant the inference that this difference is an essential and constant one.

The line of fracture, the general direction of which is commonly oblique, may be very irregular and may separate many and large splinters. The line between the condyles follows the intercondyloid notch, and is vertical and antero-posterior. In a case observed by Nélaton and reported by Trélat (loc. cit., p. 73), the mechanism of the separation of the condyles is shown plainly, the upper fragment being impacted into the lower one, but mainly on the inner side, and the separation of the condyles merely a fissure (fig. 307). Usually, however, the condyles are completely detached from each other and sometimes separated far enough

[1] Archives Générales de Méd., 1854, ii. p. 59.

to allow the patella to sink in between them, and either may be displaced backward further than the other, with a corresponding rotation of the leg since the tibia retains its connection with them. The crucial ligaments may be torn longitudinally or transversely, and then the attachment of the tibia is less close. The pointed upper fragment perforates the quadriceps muscle and the skin in a large proportion of cases; in 23 cases of supra- and intercondyloid fracture collected by Trélat the skin was perforated in 6 and the muscle alone in 6. There is also the same possibility of injury to the popliteal vessels or of pressure upon them by the end of the upper fragment.

Fig. 307.



Intercondyloid fracture of femur.

Intercondyloid fracture of both femurs is a rare and very grave injury. In a case under my care at Bellevue, the patient never rallied fairly from the shock and died in thirty-six hours; one fracture was compound by perforation of the muscle and skin in front by the upper fragment, the other was simple, but the popliteal vein was torn, and there was a large extravasation of the blood in the thigh. In each the lower end of the upper fragment was very irregular but not broken obliquely, and there was much comminution between it and the condyles; the compact layer on the posterior face of the bone was pressed in toward the centre as if the lower fragment had been bent violently backward upon the other. The injury was caused by a fall from a height of about forty feet.

Shortening of the limb is common, but the sign is one that is seldom needed for the diagnosis; in an impacted fracture it might be useful in distinguishing the lesion from fracture of one condyle alone.

Enlargement of the knee by separation of the condyles is rare, or at least is difficult of recognition; on the other hand, enlargement by effusion or hemorrhage into the joint is constant.

The prognosis is serious as regards both the life of the patient and the integrity of the joint. Of 26 cases collected by Hennequin[1] 7 died, 3 were amputated, and 16 recovered. The gravity of the injury depends mainly upon the implication of the joint and the traumatic arthritis excited thereby, which may easily end in suppuration and which in any case is very likely to result in more or less stiffness.

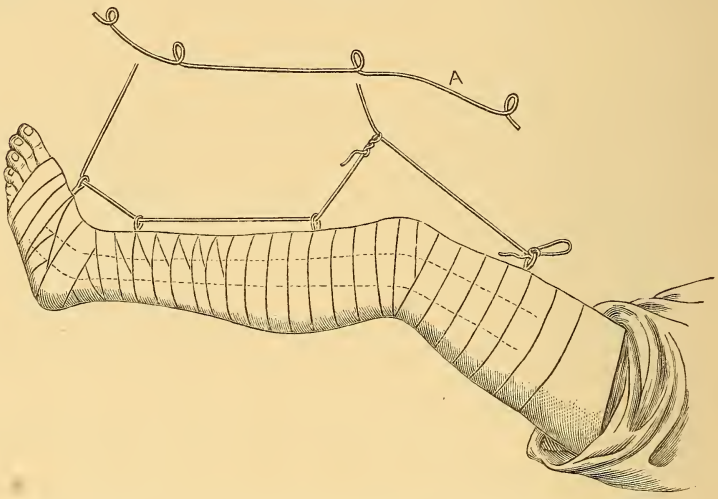
Treatment.—As in other fractures of the femur, continuous extension is the most convenient and least painful method of preventing shortening of the limb by overriding of the fragments after supracondyloid or intercondyloid fracture; but there is some difference of opinion as to the position in which the limb should be kept, whether the knee should be completely extended or partly flexed. Those who fear lest the lower fragment should be tilted backward by the traction of the gastrocnemii muscles prefer the flexed position in order that these may be relaxed. The practice, recommended a few years ago, of putting a pad in the popliteal space to prevent this tilting by pressure upon the

[1] Des Fractures du Fémur, p. 405.

fragment is very objectionable, and I cannot believe that the plan suggested by Mr. Bryant of dividing the tendo Achillis to accomplish the same object can often be necessary.

If extension in the straight position with weight and pulley fails to correct the displacement, the leg may be raised upon pillows so as to flex the knee somewhat, or Hodgen's suspended splint may be used. If the fracture is impacted or transverse and the tendency to displacement slight or absent, the limb may be simply kept on a double inclined plane, or in a wire gutter, or even encased in plaster and swung as shown in fig. 308, or in plaster splints, or the Bavarian splint. A point of capital

Fig. 308.



Plaster splints. *A* is a wire bent into loops for the purpose of suspension.

importance in the treatment is to prevent or control inflammation of the joint, and the immobilization therefore should be as complete as possible for the first two or three weeks, and if the inflammation is acute and ankylosis likely to ensue, the knee must be kept almost completely extended because the usefulness of the limb will be greatest with the joint fixed in that position.

If suppuration takes place within the joint, the pus must be promptly evacuated through a free incision with strict antiseptic precautions, and the case treated as a compound fracture.

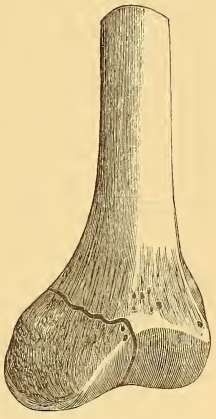
Even very grave cases are capable of a favorable termination. An Italian laborer, 43 years old, was admitted to the Presbyterian Hospital, May, 1881, with a compound fracture of the left femur just above the knee, caused by the limb being caught between the pole of a heavy wagon and a bank. The wound was on the inner side and large enough to admit the finger. I found the bone much splintered and withdrew one piece that was completely detached; it was trough-shaped, half an inch long, and comprised nearly half the circumference of the shaft. There was lateral motion at the knee-joint and I suspected an intercon-

dyloid fissure. The wound was washed out thoroughly with the carbolic solution, 1 in 20, a drainage tube put in, and a carbolized gauze dressing applied; Buck's extension, and the thigh supported on pillows. The temperature did not rise above 100°, and the patient made a good recovery and left the hospital with a good joint and limb.

C. Fracture of either Condyle.—Fracture of a single condyle may be caused by direct violence, as in a fall upon the bent knee, or by avulsion, the force being exerted through one of the lateral ligaments to tear off one condyle by bending the leg towards the opposite side. It seems not impossible that the effect observed at the elbow of force acting in the same direction might also be produced here, and the condyle on the side towards which the limb is bent might be broken off by direct pressure of the head of the tibia upon it. In a case reported by A. H. Crosby[1] the fracture was caused by a twist of the leg while the patient, a youth of 21 years, was resting his entire weight upon it.

The specimens of fracture of a single condyle are not numerous, but they show that the line may run for a considerable distance upward from the intercondyloid notch so that the fragment terminates above in a long point, or it may turn abruptly above the edge of the articular cartilage towards the side of the bone, as in figure 309, which represents a specimen given to the Dupuytren Museum by Verneuil; in this case the periosteum on the inner side and the crucial ligaments were untorn and the fragment was not displaced. (Trélat, loc. cit., p. 69.)

Fig. 309.



Fracture of the internal condyle of the femur.

In a case reported by Dr. Wells,[2] the tibia was dislocated outward and backward, and at the autopsy a thick scale of bone was found to have been torn from the side of the internal condyle, and to remain attached to the ligament. The leg became gangrenous promptly, and death took place on the fourth day. In this case the dislocation was the essential lesion, and the fracture only an incident.

The fragment may be displaced upward, or to one side, or it may be swung around so as to lie partly behind or partly in front of the femur, usually the former. As it remains attached to the tibia the first and third displacements are indicated by the posture of the leg, the second, which is very rare, by the greater breadth of the knee.

As the displacement is usually slight, and the connections untorn, the injury may easily be overlooked, or, if suspected, not recognized with certainty. In a case under the care of Gosselin (quoted by Trélat) the patient was treated for more than a month for a supposed arthritis of the knee; he grew weaker daily and died of exhaustion. At the autopsy the joint was found full of pus and one of the condyles broken. The

[1] New Hampshire Journal of Med., 1857.
[2] Am. Journal Med. Sciences, vol. x., May, 1832, p. 25.

fragments were in exact apposition, but there was no sign of repair. The diagnosis must be made upon the localized pain, ecchymosis, loss of function, and abnormal mobility and crepitation, recognized by direct manipulation of the condyle or by moving the leg laterally or in the direction of flexion and extension.

In a case reported to Dr. Hamilton[1] by Dr. Lewis Riggs, a lad 15 years old had the internal condyle broken off by the kick of a horse ; the tibia and fibula were at the same time dislocated inward and upward, apparently quitting the articular surface of the external condyle entirely. Reduction was accomplished by forcible traction, and the boy recovered with a joint that was nearly as good as its fellow.

The reported cases show a remarkable variety in their course and terminations. Some patients have recovered without greater reaction than would be expected after a simple non-articular fracture ; in others the joint has suppurated, and the case has terminated fatally ; in Dr. Crosby's case the fragment was removed six months afterwards, by operation, and the patient made a complete recovery ; and in a case first seen by Dr. Hamilton three months after the injury, the fragment remained ununited and could be moved upward half an inch with distinct crepitus and pain by flexing the knee. During the next two years the usefulness of the limb increased steadily.

The treatment consists in reduction of such displacement as may exist by acting upon the fragment through the lateral ligament and the leg, and prevention of its recurrence by keeping the leg fixed in the position to which it was brought in making the reduction. As the lateral ligaments are tense when the knee is extended, and relaxed when it is flexed, the extended position is the one which gives most security. The objection urged by Malgaigne, that it favors ankylosis, is, I think, unimportant ; we know that the common cause of ankylosis lies in the severity or the prolongation of an arthritis, not in the position in which the joint is kept. In the flexed position of the knee a slight displacement upward of the fragment could occur easily, and it would certainly pass unrecognized so long as the position was kept, and would show itself in abduction or adduction of the leg as soon as it was extended. I should, therefore, treat such a case in the extended position upon a posterior splint or in a plaster bandage with a fenestra if necessary at the joint. After three or four weeks the knee might be partly flexed if the fragment had lost its mobility, but not otherwise. In short, the condition resembles a severe sprain of the joint, and should be similarly treated. I have never seen any notable impairment of function follow retention of the limb in the extended position for three or four weeks after a severe sprain with lateral motion at the joint, while a genu valgum or varum would be a serious deformity, and might restrict the usefulness of the limb much more than a limitation of flexion would.

The great importance of complete immobilization is shown by the failure of union in some of the cases and the suppuration of the joint in others.

[1] Loc. cit., p. 493.

Joints have been safely incised or aspirated of late in recent articular fractures to empty them of the effused blood and synovia, and it may be that the effusion will render such interference proper in some cases, but I should be very loath to undertake it, even by aspiration, unless the indication was very positive. On the other hand, it is proper to incise the joint, wash it out, and drain it at the earliest possible moment after suppuration has begun.

CHAPTER XXVI.

FRACTURES OF THE PATELLA.

According to the tables given in Chapter I., fractures of the patella represent from one to two per cent. of all fractures. They are much more frequent in men than in women, and in middle life than in childhood or old age, although Malgaigne maintains that the proportion of fractures to population increases with each decade. The youngest of Malgaigne's patients was 11 years old, and he knew of no other younger than 17 years. The youngest patient in the 127 cases collected by Dr. Hamilton was 5 years old, and the fracture was very different from the usual one since only a small piece was broken from the margin of the bone by a direct blow; his next youngest case was 16 years old, and in this also the fracture was by direct violence.

The *cause* may be direct or indirect, a blow or a fall upon the patella or the sudden vigorous contraction of the quadriceps femoris, as in an effort to avoid a fall. The statistics that have been collected to show the relative frequency of these two varieties vary very widely and are, I think, untrustworthy because of the difficulty, or rather the impossibility, in many cases of recognizing the mode in which the fracture has been produced. The patient slips or stumbles, makes an effort to save himself, falls, and the patella is found to be broken. He is unable to say whether he struck upon the patella or upon the tuberosity of the tibia, whether directly in front or upon the side, or, and this I have met with several times, he asserts that he fell upon the patella because he knows it is broken, and cannot understand that the lesion could have been produced in any other way. If the examination is pushed, and the question asked, "how do you know it?" the answer is often "why, it *must* have been so." Unfortunately this sort of reasoning is not confined to the patients, and some of the statistics are colored by the views of those who make them up.

My own conviction is that the efficient agent in the great majority of cases is the contraction of the quadriceps, and the grounds for this belief are the numerous cases in which this mode of production can be clearly demonstrated, the practical impossibility of producing any but a comminuted fracture experimentally by direct violence, and the position of the patella, which is such that the blow is rarely received upon it in a fall.

The question whether muscular contraction breaks it by direct traction or by bending it over the convexity of the condyles is of purely academical interest, and in most cases it cannot be answered positively because the position of the bone at the moment of fracture with reference to the condyles cannot be known. In a few cases the fracture has

been caused, beyond question, by simple traction without bending or cross-strain, as in a case reported by Garreau[1] in which a second fracture by muscular action occurred in the upper fragment twelve years after the first fracture had healed with a separation of four centimetres (1⅗ inches). In others it is equally certain that the traction of the ligamentum patellæ was inclined somewhat backward from the vertical axis of the patella, and that the fracture took place when the limb was in nearly complete extension, and the upper part of the patella consequently resting on the condyles.

The commonest clinical form of fracture by muscular action is the violent effort made by the individual to save himself from falling, an effort in which the extensor quadriceps is powerfully contracted. The following cases illustrate the different forms.

Sir Astley Cooper (case 129) tells of a lady who "descending some stairs placed her heel near the edge of one of the steps, and was in danger of falling forwards, when throwing her body somewhat backward to prevent the fall and to straighten the knee, the patella snapped asunder." Ledran, in 1753, reported to the Académie de Chirurgie the case of a nun who broke her patella in rising from her knees after prayer. In Fielding's case it was broken by the effort to raise a heavy basket, and in Boyer's by the effort the patient, a coachman, made to save himself from falling backward from his seat. In other cases it has been caused by jumping, dancing (on the stage), kicking, in stepping off a horse-car in motion, and in trying to avoid a fall while walking. Simultaneous fracture of both patellæ by muscular action alone has also occurred. Thus, in a case mentioned by Desault[2] a man who had just undergone lithotomy broke both patellæ in a convulsive spasm; and in another reported by Marcy,[3] a large heavy woman 38 years old made a violent effort to save herself from falling while walking in the street, felt "something give way in both knees," and sank to the ground. On examination both patellæ were found to be fractured transversely near the middle, the upper fragment lying two inches above the lower one. Valette tells of a porter who slipped while carrying a heavy burden up a staircase, made an effort to save himself, and fractured both patellæ; and Johnston[4] tells of a woman 33 years old who broke both by tripping upon a door-mat. "In the act of falling forward she distinctly heard a crack and felt something give way;" the separation in this case was three-fourths of an inch. A man[5] while jumping in leap-frog felt as if he had received a blow on the legs and fell; he had sustained a transvere fracture of each patella.

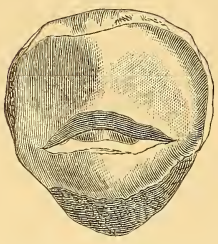
In a few cases there is reason to think that a blow upon the bone has cracked it or originated some process in it by which its complete fracture by muscular action shortly afterward was made easy.

Pathological Anatomy.—In the great majority of cases, it may perhaps be said in all in which direct violence is not certainly the cause, the fracture is transverse or slightly oblique, and usually at or just below

[1] Revue Médico-Chirurg., 1853, p. 375.
[2] Œuvres Chirurgicales, 3d ed., vol. i. p. 252.
[3] Boston Med. and Surg. Journal, vol. xci., 1874, p. 362.
[4] Lancet, 1873, vol. ii. p. 661.
[5] Med. Times and Gazette, Oct. 9, 1880.

the middle of the bone. In the cases collected by Dr. Hamilton 22 were recorded as below, 7 above, and 16 at the middle. The only instance of incomplete fracture of which I have knowledge is a specimen, apparently without history, in the Musée Dupuytren (fig. 310). It is described by Berger[1] as a transverse fracture that has largely interested the articular surface of the patella and its cartilage, with a separation at the centre of six millimetres. There is no trace of fracture on the anterior surface. There is some doubt, however, as to the exact character of this specimen, and some reason to think that it is the same as one represented by Malgaigne in his Atlas (plate 14, figs. 2 and 3) as a specimen of bony union after complete fracture.

Fig. 310.

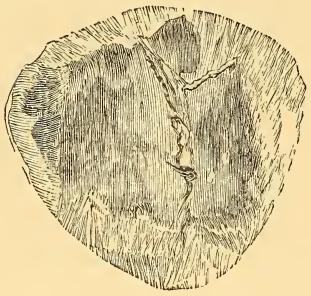


Incomplete fracture of the patella. Articular surface.

Poland[2] quotes two cases of fracture without division of the cartilage, one a gunshot fracture reported by McLeod, the other deserving to be classed as a wound of the bone rather than as a fracture, for the patient fell and struck his knee against the edge of a cutlass; the cut is said to have extended through the bone but not through the cartilage. Poland made some experiments in connection with these two cases and found he could divide the patella completely with a chisel and still leave the cartilage untorn.

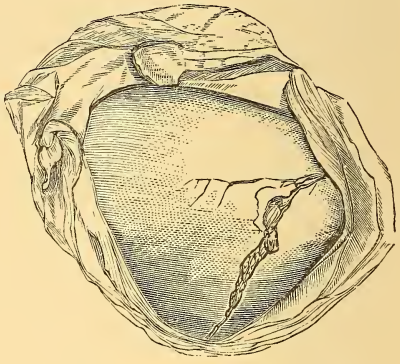
Vertical fracture of the patella (fig. 311) is not very rare and has

Fig. 311.



Vertical fracture of the patella. (Holmes.)

Fig. 312.



Oblique fracture of the patella.

always been the result of direct violence. The fragments may be of equal size, or one may be much larger than the other. With these may also be classed oblique fractures caused by direct violence.

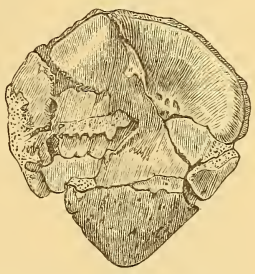
Multiple or comminuted fractures (fig. 313) are always due to direct violence, and are characterized by their slight displacement and their tendency to bony union. It has been noticed, however, that when there were two main lines of fracture, one transverse and the other vertical,

[1] Dict. Encyclopédique des Sc. Méd., art. Rotule, p. 257.
[2] Medico-Chirurg. Trans., 1870, p. 49.

the fragments lying above the transverse fracture, and those lying below it would each unite by bone, but the union between the two pairs or the two groups would be fibrous and long.

The displacement after transverse fracture is ordinarily well marked, and its degree is modified by the extent to which the overlying fibrous tissues and the aponeurosis on each side are torn. Berger refers to two specimens in the Musée Dupuytren in one of which the fibrous covering in front is completely preserved, and the fracture, which is exactly transverse and in the centre of the bone, is there indicated only by a slight depression, while it is very apparent on the articular surface; the patient walked to the hospital. In the other there is fibrous union, and the separation is apparent only on the articular surface and especially at its outer border.

Fig. 313.



Comminuted fracture of the patella. Bony union. Exuberant callus at several points. (Gurlt.)

The displacement is most marked in those fractures in which the muscles have been vigorously contracted at the moment of the accident in the effort either to avoid a fall or to do some act requiring the exercise of considerable force. Under such circumstances the separation is usually an inch or more. It is due, of course, in great part to the retraction of the quadriceps which draws the upper fragment upward, but not entirely so, for from the moment that the joint becomes at all distended by an effusion of either blood or synovia into it, the fragments are pressed apart by the liquid to meet the need of more space. As a result of this it also follows that the separation grows less as the effusion diminishes.

A third cause, which acts less promptly, is the retraction of the ligamentum patellæ. It was pointed out long ago that after union with much separation of the fragments the ligament was much shorter than its fellow of the opposite side; in one of Malgaigne's[1] cases it was shortened one half, measuring only three centimetres. Gerock,[2] basing the statement on a large number of exact measurements, claims that it is the essential cause of the separation. It seems more probable that it is one of the consequences.

The other displacements are more readily recognizable after union. They are lateral displacement and angular displacement, the angle pointing forward, backward, or to one side. Lateral angular displacement appears to be commonly the result of uneven stretching of the fibrous union after the patient begins to use the limb; anterior angular displacement is not only produced by the pressure of pads or bandages above and below the fragments when the latter are in contact, or nearly so, but it is also the inevitable effect of separation by distension and may go so far that the broken surface of the lower fragment is turned directly forward and unites with the soft parts overlying the gap, as in figure 314;

[1] Atlas, Plate 14, fig. 4, and p. 17.
[2] Inaug. Dissertation, Tübingen, 1872, quoted by Berger.

Fig. 314.

Fibrous union with great separation, after fracture of the patella. The band adheres to the broken surface of the lower fragment. (Holmes's Syst.)

and in at least one specimen, in the Musée Dupuytren, the articular surface of the lower fragment is united to the broken surface of the upper one, the former presenting an angular displacement of 90°.

Symptoms.—In fractures by muscular action, with or without a fall, a sharp crack may be heard and the patient is usually unable to use his limb. In a few cases he has walked, and, indeed, in most it is possible to walk backward, keeping the knee extended by the pressure of the heel on the ground, or even to walk forward if the uninjured limb is advanced and the other swung up to but not beyond it.

The knee becomes promptly swollen by an effusion of blood or synovia into it and by tumefaction of the soft parts, especially if a blow has been received upon it, and the two fragments, separated usually by a well-marked interval, can be made out and their independent mobility recognized. This mobility may be very slight if the fragments are close together, but then crepitation may perhaps be perceived.

The subjective symptoms are moderate pain when the limb is at rest, increased by movement, and inability to extend the leg or to raise the heel from the bed. It must be remembered that in rare, entirely exceptional cases the fibrous covering of the bone may remain untorn and constitute a sufficient connection between the fragments to make a limited use of the limb possible.

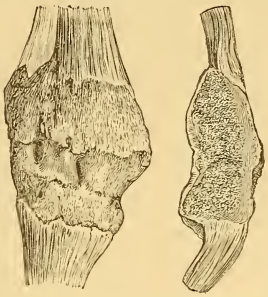
In vertical or comminuted fractures the signs recognized by palpation will vary in accordance with the differences in the lines of the fracture, and in the former active extension will be prevented only by the pain attending the effort.

Course and Terminations.—The arthritis which follows the fracture is usually moderate and subsides within the first fortnight. When the swelling forms slowly by exudation from the synovial sac the blood from the fracture mixes with it evenly, but when it forms immediately it is composed mainly of blood which forms a solid homogeneous clot adherent to the surfaces of fracture. The swelling diminishes as the arthritis grows less acute and as the synovia and serum are reabsorbed, and in all probability the blood clot disintegrates under the action of the liquid in which it bathes, and disappears as it does under similar conditions elsewhere. Sometimes the prepatellar bursa becomes distended either by an effusion poured out within itself, the result of direct violence, or by the escape into it through the fracture of the effusion formed within the joint.

The surfaces of fracture and the torn tissues form granulations in the usual manner, and the great differences in the result, differences in the composition and length of the bond between the fragments, depend upon

the proximity of the fragments to each other. If the fractured surfaces are in close contact the granulations unite and constitute a close fibrous

Fig. 315.



Bony union of the patella. (Bryant.)

Fig. 316.

union or a bony one (fig. 315); if, on the other hand, they are at some distance from each other the evolution of the new tissue does not pass beyond the fibrous stage, and the union is by a thick fibrous band of greater or less length (fig. 316); or the formation of tissue is very scanty and the fragments are held together only by the overlying soft parts more or less condensed by the irritation following the injury (fig. 314). In the latter case the tilting of the lower fragment brings its broken surface into contact and union with the overlying parts. The length of this fibrous band varies in different cases between a few lines and several (five or six) inches, and sometimes its length is increased notably by flexing the knee.

Hypertrophy of the fragments, occurring during and subsequent to repair, is frequently noticed, and sometimes also the production of irregular bony points from the fractured surfaces or of isolated nodules within the connecting fibrous band.

Even when the union is so close that the fragments show no independent mobility it is impossible to say at first that the union is bony. The test is found in time and use, and it is quite common to see a gap which is very slight at the time treatment ends increase to the length of half an inch or even more in the course of a few months; and this separation may be greater on one side than on the other, as in a case reported by Coale,[1] in which there was no recognizable gap at the end of treatment, but ten years afterwards there was separation to the distance of an inch on the outer side and one-eighth of an inch on the inner. Dr. Edward T. Caswell[2] reports a case in which after four years the separation is not more than one-eighth of an inch, although it was one and a half inches at the time of the accident. In such a case it might reasonably be supposed that the union was bony, and yet the same surgeon quotes a case[3] to show how deceptive this appearance may be. "The

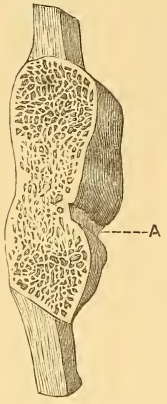
[1] Boston Med. and Surg. Journal, vol. liv. p. 402.
[2] Holmes's System of Surgery, Am. ed., vol. i. p. 952.
[3] Boston Med. and Surg. Journal, May 2, 1878, p. 572.

union was so very close and firm that after removal, with all the force that could be used, not the slightest motion between the fragments could be felt, and it would have been regarded as a bony union if it had not been either sawed or macerated. Three longitudinal sections, however, were made through the bone, and it was proved, so far as these would show, that at no points were the fragments united by bone." Berger[1] reports a similar case under his own care, in which, ten years after the accident, "the patella seemed identical with its fellow, and only a slight transverse groove marked the seat of the former fracture. No abnormal mobility could be recognized on handling the fragments, and the callus might have been thought to be bony, but on relaxing the quadriceps completely by extending the knee and flexing the thigh on the pelvis slight mobility could be plainly detected.

These two cases show with how much reserve assertions of recovery with bony union should be received. Clinical proof of such union is almost impossible.

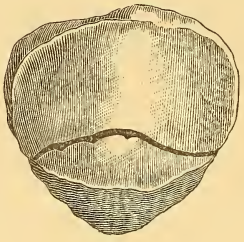
That bony union of a simple transverse fracture can and does occur has been demonstrated anatomically. Fig. 315 represents a specimen of unknown history, but apparently of such union, preserved in Guy's Hospital Museum, and described by W. King in the Guy's Reports, Series 1, Vol. VI. Berger figures another preserved in the Musée Dupuytren (fig. 317), and quotes a third from Gerock, in which the separation, nevertheless, was nine millimetres. The specimen figured by Malgaigne (figs. 318 and 319) was thought by Houel, the Director

Fig. 317.



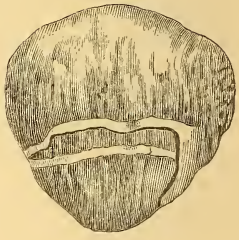
Bony union after fracture of the patella. Specimen 201 of the Musée Dupuytren.

Fig. 318.



Fracture of patella. Articular surface.

Fig. 319.



Fracture of patella. Anterior surface (bony union).

of the Dupuytren Museum, to be one preserved in that museum, and considered by him as incomplete fracture, not as bony union. Malgaigne quotes from Camper a case in which a bony bridge united the two main fragments and an intermediate splinter in the median line, while the

[1] Loc. cit., p. 267.

union on the sides was fibrous; and there are quite a number of specimens in existence showing the formation of bony stalactites of greater or less length, and always, I believe, upon the lower fragment.

The length of time necessary to consolidation cannot be positively determined, because of the tendency to the elongation of the fibrous band under use, a tendency which seems to exist in some cases for years, and in others for only a few weeks. Whether or not this difference depends solely upon the length of time during which the limb is kept at rest immediately after the injury I have no means of knowing, but it is certain that early use of the joint favors the lengthening.

Rupture of the band and iterative fracture of the bone have been frequently observed at longer or shorter intervals after the original accident. Mr. Bryant refers to a case in his own experience in which one patella had been broken twice and the other three times, and Moore mentioned a similar case in the discussion on Poland's paper (*Brit. Med. Journal*, 1870, i. p. 94), in which suppuration occurred after the third fracture, and caused death. Fig. 320 represents a specimen of supposed multiple fracture from Bryant's collection.

Fig. 320.

Multiple fracture of the patella. (Bryant)

In several cases this rupture of the band has caused at the same time a wound of the integuments, and opened the joint. Poland quotes three such cases: one reported by Chas. Bell and treated by amputation; another by Dr. Croker King, in which the injury was caused by having the leg forcibly bent in a fall five months after the first fracture, the patient recovering in thirty-three days; and one by Seutin after an interval of seven months—amputation was done four months later. Erskine Mason[1] reported a similar case to the N. Y. Pathological Society; the accident occurred after an interval of a year, the separation being about three-fourths of an inch, and the joint quite stiff. The patient fell with the leg bent under him; amputation was done, and he died. Roberts[2] mentions briefly a similar case; the patient was a woman, the knee stiff, and the cause of the rupture a fall. The patient recovered "with some separation of the fragments and a partially stiff joint."

The occurrence of this accident is evidently favored by stiffness of the joint, and the mechanism appears to be the tearing away of the lower fragment by the violent flexing of the leg, the upper fragment being held in place by the contraction of the quadriceps and the adhesions of new formation between it and the condyles. The laceration of the overlying soft parts is the consequence of their condensation and adhesion to the fragments.

Compound fractures, in which the wound of the soft parts was caused in the same manner, have been reported by Poland (*Medico-Chirurgical Transactions*, 1870, p. 49) and by Pelletan. In that of the former the patient wounded the skin over the patella by a fall; eight weeks later, when the wound had almost healed, he broke the patella in trying to

[1] N. Y. Med. Record, 1875, p. 211.
[2] Bryant's Surgery, 3d Am. ed., p. 853.

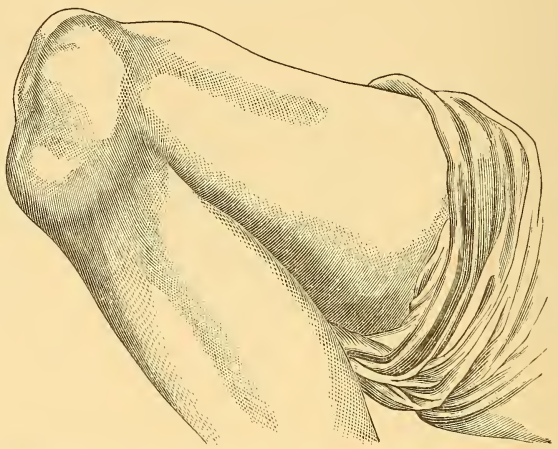
save himself from falling, the cicatrix in the skin tore open, and the fracture thus became compound. The joint suppurated, and resort was had to amputation.

In a compound comminuted fracture reported by Schede[1] two-thirds of the bone became necrosed; the joint was drained, and the bone was reproduced. At the time of the report the patient was able to walk, and there was some motion in the joint.

The injury may result in more or less loss of function of the limb by rigidity of the joint or incompleteness of the repair, and this loss may persist for a longer or shorter time. Rigidity is always well marked when the limb is first taken out of the splints, and its degree and persistence seem to depend more upon the severity of the arthritis set up by the fracture than upon the length of time during which the limb has been immobolized, or the age of the patient. It is not safe to attempt to overcome the rigidity by forcible flexion of the knee, lest the band uniting the fragments should be ruptured or stretched; it must be left to time and ordinary use of the limb.

The disability due to the failure to obtain close bony union is ordinarily slight, and not noticeable in the common everyday use of the limb, yet its degree varies by no means directly with the length of the band that unites the fragment. Quite a number of cases have been reported in which the limb was very useful, notwithstanding a separation of from two to five inches, and in the case represented in fig. 321, which

Fig. 321.



Extreme separation of the fragments after fracture of the patella. (From a photograph)

was under my care in Bellevue Hospital, with fracture of the other patella, four years after the accident to the one shown in the cut, the patient walked easily and securely, although there was separation to the distance of $4\frac{1}{2}$ inches when the limb was extended, and although there was no power of active extension, except to a very slight degree through

[1] Deutsche Gesellschaft für Chirurgie, 3d Congress, 1874, p. 185.

the aponeurotic attachments in the position of nearly complete extension. All writers mention similar cases. On the other hand, the disability has been almost complete in a few instances in which the union was quite close, but it is not clear that it was due solely to the length or weakness of the bond of union.

The weakening when present is shown in both the force and the range of active extension. The actual strength of the limb is found to be less, and in the more marked cases active extension is possible only when the limb is nearly extended. Some patients are unable to raise the heel from the bed without some previous flexion of the knee, or, if standing, to carry the limb forward without bending the knee. It must be remembered, however, that this disability, even when extensive, does not always show itself permanently in the ordinary use of the limb, and the patients are able to walk without limping. It appears when they are called upon for a greater effort, as in running, carrying a heavy burden, or going up or down stairs. Singular as it may seem, it is easier for such an individual to ascend a staircase or an incline than to descend it.

When the distance between the fragments can be increased by flexion of the knee it proves that almost the whole of the quadriceps has been rendered useless for the extension of the leg, and that such power of active extension as still exists is exerted mainly through the lower fragment alone by the fibres of the vasti that are attached directly to it, and perhaps in some manner by the aponeurotic attachments of the upper fragment. The simple lengthening of the tendon (patella) ought not, theoretically, to diminish the power of extension any more than the equivalent lengthening produced so often by shortening of the thigh after fracture; at the most it should weaken it only at and near the position of complete extension; but it is found, on the contrary, that in the feeblest cases that is the only portion of the range of motion in which active extension is possible. The cause, therefore, must be sought, not in the lengthening of the cord, but in the creation of attachments between the upper fragment and the femur, which prevent the former from moving up the thigh when the quadriceps contracts, and thus effectually divert its action from the tibia.

A compound fracture is, of course, much more serious than a simple one, endangering the life of the patient as well as the integrity of the joint. The statistics are rather scanty, and are open to the objection which applies to all such lists made up of reported cases, that the proportion of favorable cases reported is larger than that of the unfavorable ones. On the other hand, the modern methods of treatment of wounded joints yield much better results, and there is good reason to hope that the percentage of success will be actually even higher in the future than that of the partial statistics of the past. Those statistics are as follows: Poland (loc. cit.) collected 69 cases, in 40 of which the fracture was caused by a fall or a blow with a blunt instrument. Bouchard and Berger collected 29 others. Of these 69 (40 + 29) cases 7 were treated by amputation; of the remaining 62, 18 died and 44 recovered. In 17 of these 44, the functions of the joint were preserved almost unimpaired, in 11 the range of motion was limited, and in 16 there was complete ankylosis. In 14 of the 17 the joint did not suppurate; in several

of those that terminated in ankylosis the suppuration was profuse and the life of the patient threatened seriously.

Treatment.—The objects of treatment are twofold: to secure close union of the fragments, and to prevent or control inflammation of the joint and the adjacent tissues. The multiplicity[1] of the methods prepared to meet the first indication points out only too clearly the difficulty of accomplishing it and the insufficiency or unfitness of the means proposed. The small size of the fragments and the convexity of the surface of the condyles upon which they rest when the limb is extended, make it difficult to act upon them directly without creating some angular displacement; they tilt forward at the line of fracture if they are brought together, and only too often it is found that the means used to hold them together after the adjustment has been made fail to accomplish their purpose. The different methods may be roughly classed as seeking to act: 1st, by simply relaxing the extensor muscles, keeping the knee extended and the hip somewhat flexed; 2d, immobilization of the fragments by a firm ring or mould inclosing them; 3d, by pressure, fixed or elastic, upon the fragments or the adjoining soft parts in opposite directions; 4th, by direct action upon the fragments by metal points; and, in addition, measures, considered the most important of all by some, to prevent or subdue the arthritis and to hasten the absorption of the effusion, measures which may be used in connection with or previous to the employment of the mechanical ones already mentioned.

The methods of local treatment usually employed under other circumstances to control inflammation or promote absorption of the effusion may be usefully employed here; cooling lotions, lead and opium, the ice-bag, irrigation, and poultices, are the ones in most frequent use. Guyon recommends blistering. Aspiration of the joint, to remove its increased contents and thus favor coaptation, was proposed and practised about 1870, but was not received with much favor, because of the risk of provoking suppuration of the joint thereby. A successful case of its use, by Labbé, was followed by another by Dubrueil,[2] in which the puncture suppurated and led to a purulent arthritis; the final result was not reported.

Of late the plan has been again employed in connection with antiseptics. Schede[3] punctures the joint to remove the blood and synovia, washes it out with a three per cent. solution of carbolic acid, continuing the washing until the water returns clear, covers the puncture with antiseptic cotton, binds it down and fixes the fragments together with a "testudo"[4] of adhesive plaster over which he applies a flannel bandage and then a dressing of plaster of Paris. He renews the entire dressing during or at the end of the first week, and then again once or twice at intervals of a week or two in order to make sure of the adjustment.

[1] Berger says he made a list of ninety-one different methods of treatment, excluding five or six concerning which he was unable to obtain sufficient details.

[2] Bull. de la Société de Chirurgie, Oct. 1872, p. 438.

[3] Centralblatt für Chirurgie, 1877, p 657.

[4] This is composed of many long narrow strips of adhesive plaster applied above and below the fragments, so that they reach from the middle of the back part of the thigh to the middle of the calf, crossing in front of the knee and pressing the fragments together.

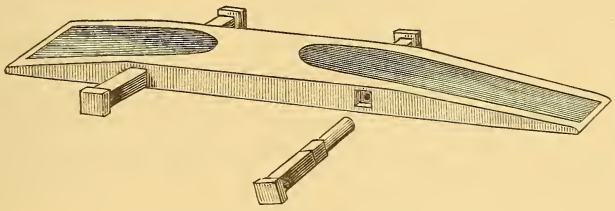
He reports six cases in which he used this plan with good results. The injection causes no pain, it is followed by an effusion into the joint, and it is this effusion and its absorption which render the readjustment necessary.

Corroborative testimony as to the value and safety of the method is furnished by the success following the similar treatment of compound fractures and of operations for the relief of ununited fracture or of fracture with separation of the fragments. I have no experience with it, but I certainly should not employ it in any case in which the effusion was of moderate size and in which the fragments could be brought together. There are other methods of avoiding excessive reaction and promoting absorption which involve less risk.[1]

A description of all the methods recommended to keep the fragments in contact is not required. The following have been selected as the ones most deserving mention.

Dr. Agnew[2] uses a splint which is "a piece of pine board somewhat convex longitudinally on the upper surface, thirty inches long, and five inches wide at one end, tapering to four inches at the other. On each side, a short distance above and below the middle of the board, are to be bored two holes, into which are fitted four pegs with square heads (fig. 322). This splint must be well padded and placed under the

Fig. 322.



Agnew's splint for fracture of the patella.

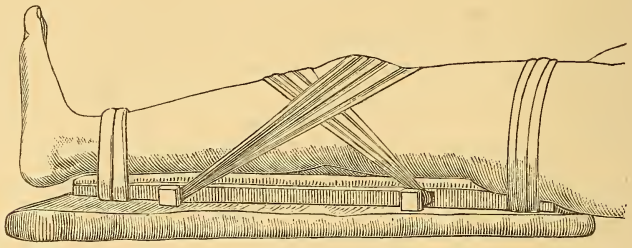
thigh and the leg, the limb being at the same time moderately elevated. Below the knee and the lower fragment are next to be applied, partially overlapping each other, two or three strips of adhesive plaster, each three-quarters of an inch wide and thirteen inches long. These strips are brought together at their extremities and wrapped round the upper pegs. This secures in position the lower fragment. Five strips of plaster of like length and width are next applied three or four inches above the knee, descending toward the joint, each strip overlapping one-third of the preceding one. Bringing the ends of the plaster together they are to be wound around the lower pin, when, by screwing or twisting the pegs of the two sides, the lower fragment will be brought into near apposition with the upper. To prevent the broken surfaces from tilting forward, a broad strip of plaster may be drawn over the line of approxi-

[1] Disastrous consequences have followed this treatment in some cases, death by carbolic acid poisoning, suppuration of the joint, and secondary amputation. See Fowler in Annals of Anatomy and Surgery, June, 1882, and Wyeth in Med. Record, June 3, 1882.

[2] Surgery, vol. i. p. 974.

mation and fastened to the splint below. A roller is now applied above and below, which secures the thigh and leg to the splint (fig. 323).

Fig. 323.

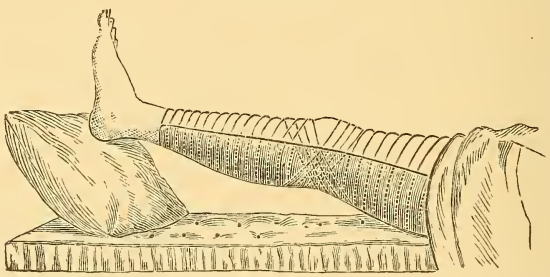


Agnew's splint applied.

As the swelling subsides all that is necessary to maintain the adjustment is to tighten the strips by screwing up the pegs to which they are fastened. By this plan the removal of the dressing is rendered unnecessary until the cure is complete. Between the third and fourth weeks the strips may be separated from the pins, the knee gently moved so as to overcome stiffening, and the dressing again adjusted. This process should be repeated every five or six days, or until the fifth week, when the splint may be laid aside and the patient be placed on crutches."

Dr. Hamilton's[1] method of treatment is as follows; the limb is extended, the foot elevated about six inches, and a moulded splint made of leather or other light firm material fitted to the back of the thigh and leg; it should extend from above the middle of the thigh to two or three inches above the heel. The splint is then removed and fitted with a covering of cotton cloth, with the double object of protecting the skin and of supplying a basis to which the turns of the roller bandages afterwards applied can be stitched (fig. 324).

Fig. 324.



Hamilton's dressing for fracture of the patella. The final turns of the roller in front of the knee are not shown in the cut.

The splint is then fastened to the limb with a roller bandage, the region of the knee and about three inches on each side being left uncovered. Then "while an assistant approximates the fragments with his

[1] Loc. cit., p. 522.

fingers, the surgeon makes two or three turns with a third roller around the limb and splint, close above the knee; after which the roller descends below the knee, and an equal number of circular turns are made close below the lower fragment of the patella; and finally a succession of oblique and circular turns are made above and below the fragments, which turns are to approach each other in front until the whole of the patella is covered—the last turns being again circular. The dressing now being completed, the rollers are carefully stitched to the cover of the splint throughout its whole length, on both sides," and the foot kept elevated.

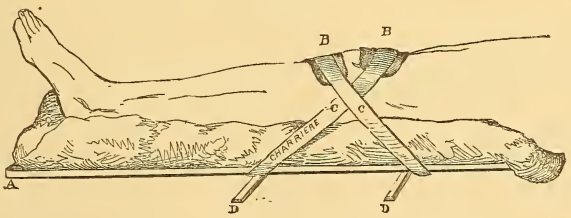
"On the second or third day the swelling of the knee will be found, probably, to have subsided somewhat, and the oblique turns of the bandage from above and below the patella will need to be tightened. This will be done by overstitching them with strong thread, taking care to do this on both sides and so far back that the doubling of the cloth will not be over the sides of the exposed portions of the limb. The same thing may require to be done every day, or every second or third day, for two or four weeks."

After the fourth week he makes gentle passive motion daily and allows the patient to go about on crutches, but requires him to wear a similar but shorter splint for three or four months longer.

Mr. Bryant advises against any pressure upon the bone and says he has known secondary suppuration, necrosis, and joint complications of a serious nature to be caused by it. He also advises that no dressing should be applied during the first few days or until after all inflammatory action has subsided.

Immovable plaster or starch dressings should not be used, at least not without a large fenestra over the front of the knee through which the position of the fragments can be noted and pressure made upon them if necessary. The best results I have obtained have been by a light plaster of Paris bandage extending from the upper third of the thigh to the ankle and reinforced by a strip of metal or wood included in it poste-

Fig. 325.

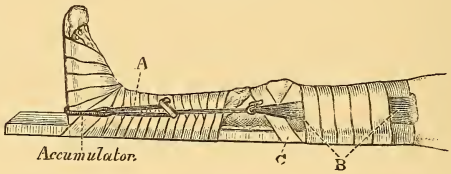


riorly, with a fenestra eight or ten inches long and seven or eight inches wide over the front of the knee. On each side of the dressing above and below the fenestra are fixed pieces of wire or hooks for the attachment of rubber bands which are passed above and below the fragments so as to press the lower one upward and the upper one downward. The skin is protected by strips of lint or a thin layer of cotton, and the traction of the rubbers is diminished or increased from time to time accord-

ing to the condition of the skin. The principle underlying this method is found in many others that have been in use for many years, one of the earlier forms of which, used by Laugier, is represented in fig. 325. Its principal merits are the ready inspection of the parts which it permits and the modification of the pressure to suit the needs of the case and the condition of the skin.

A similar method of drawing down the upper fragment by an elastic or yielding traction is found in the various plans by which the traction is applied to the skin of the anterior surface of the thigh by strips of adhesive plaster. A strip cut somewhat in the shape of the letter U, but with the curved part very much broader than the sides, is fastened upon the thigh above the patella in such a manner that its sides pass down on each side of the leg and are attached to a weight by a cord passing over a pulley at the foot of the bed or to an India-rubber "accumulator" as shown in figure 326. Through the adhesion of the plaster to the skin

Fig. 326.

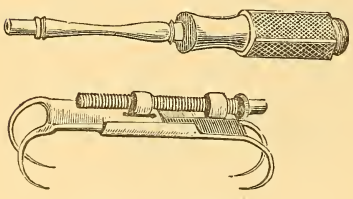


Treatment of fracture of the patella by elastic traction.

of the anterior surface of the thigh the quadriceps is drawn down and with it, of course, the upper fragment. Moderate pressure by a bandage, elastic or inelastic, upon the lower fragment aids to keep the two in contact. I think it would be equally efficient to tie the cords attached to the ends of the plaster about the foot-piece and to tighten them whenever needed.

Malgaigne sought to act directly upon the fragments by a pair of double hooks adjustable upon each other (fig. 327). The points are passed through the skin and engaged, the one pair at the upper part of the upper fragment, and the other at the lower part of the lower one, and then brought together by means of the screw until the fragments are accurately coaptated. The objections to the method seem to be mainly sentimental, the dislike to puncturing the skin and causing pain; but in at least one instance a fatal erysipelas has originated in the punctures. The probability of the recurrence of such an accident has been greatly diminished by the improvement in the hygienic condition of our hospitals, and in our methods of treating wounds; but still the possibility is perhaps a legitimate objection to the method. The hooks must be inserted with a good deal of force, so that

Fig. 327.

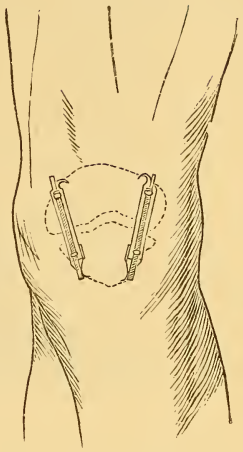


Malgaigne's hooks.

their points will penetrate to the bone and thus insure the fixity which is the only excuse for their employment, and which may be easily lost if the hooks are engaged only in the tendon.

Dr. Levis has modified the hooks by separating them into two independent pairs, which may be placed obliquely (fig. 328).

Fig. 328.

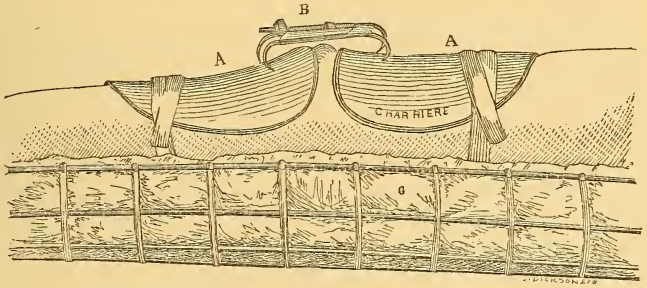


Levis's modification in place.

Trélat modified it by fixing the points of the hooks in pieces of gutta percha moulded to the limb above and below the fracture (fig. 329); and this again was modified by Verneuil and Le Fort, who substituted an elastic cord for the hooks, the former passing it through holes made close to the edge of the gutta percha plates, the other passing it about hooks imbedded in the plates while they were heated in the flame of a candle (fig. 330).

Kocher[1] has tried to bring and keep the fragments together by passing a strong silver wire vertically through the joint under them, from below upwards, by means of a curved needle, and twisting its ends together firmly in front. He

Fig. 329.



Trélat's dressing for fracture of the patella.

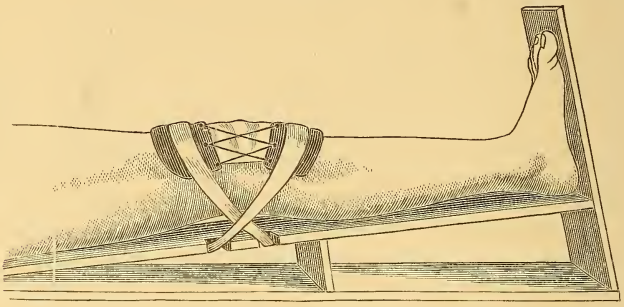
has done this with antiseptic precautions in two cases of simple fracture, but the result—notable diminution of the separation with fibrous union—is not sufficiently good to outweigh the mistrust which the proposal excites, although in neither case was there inflammatory reaction or pain.

In *compound fractures* the published experience of the last few years indicates plainly the method that should be pursued. If the wound is small, the injury very recent, and the adjoining soft parts not bruised or lacerated, it may be proper to try to convert the fracture immediately into a simple one by an occludent dressing; but if such an attempt should be inappropriate or should fail the joint should be washed out very thoroughly with a five per cent. solution of carbolic acid, a short drainage tube should be placed on each side, extending of course into the joint, an antiseptic dressing placed over all, and the limb fixed in the

[1] Centralblatt für Chirurgie, 1880, p. 321.

extended position upon a posterior or a bracketed splint. If all goes well the drainage tubes should be removed during the first week.

Fig. 330.



Le Fort's dressing for fracture of the patella.

In a case reported by Dr. Fitzau[1] a comminuted compound fracture was caused by the kick of a horse. It was treated in the manner above described, and on the twenty-seventh day when the sixth Lister dressing was removed the wound was small and superficial and the joint entirely free from swelling and pain, and at the end of two months the joint was almost as good as before the accident.

In a case mentioned by Dr. Maclaren,[2] a man was brought into the hospital thirty-six hours after having received a compound transverse fracture of the patella by direct violence. The wound was two inches long, was smelling badly, and was discharging sanious fluid. It was irrigated for two hours with a five per cent. carbolic solution and then dressed with the gauze. Thirteen days afterwards the wound had become superficial, and the joint free from inflammation, and very shortly afterwards the dressings were discontinued and an extension apparatus applied to bring the fragments together.

Ununited Fracture.—The absence of dangerous complications and the successes obtained in such cases and in similar ones involving other joints have led some surgeons to cut down upon ununited fractures of the patella and even upon recent ones in order to wire the fragments together.

A case of refracture with separation of $2\frac{1}{2}$ inches in a man 27 years old, treated successfully in this manner with supposed bony union and good use of the joint, was reported to the Medical Society of London by Mr. R. Bell,[3] and at the following meeting of the society two cases of recent fracture thus treated were reported by Mr. Rose,[4] in each of which the operation was done on the nineteenth day.

In Mr. Bell's case the fracture took place September 24, 1878, the refracture January 31, 1879, and the operation in the following July.

[1] Centralblatt für Chirurgie, 1881, p. 749.
[2] Lancet, January 31, 1880, p. 160.
[3] Lancet, November 1, 1879, p. 657.
[4] Lancet, November 22, 1879, p. 767.

It was found necessary to divide the lateral attachments of the patella and the whole of the rectus femoris and tendon subcutaneously three inches above the upper margin of the bone before the fragments could be brought together. The drainage tubes were removed in the fourth week, and the silver wires after 2½ months. When shown to the Society in the following October, the patient could walk without a cane, and could go up and down stairs, and the joint was daily becoming more useful. Its range of motion was then about 60°.

In Mr. Rose's cases the bone was exposed by a longitudinal incision in the median line, its surfaces freshened, the lateral attachments freed a little, and the pieces wired together at two points, the wires running close to the articular surface, but not through it. He drained with horse-hair and took out the wires in the sixth week.

In the discussion that followed the report of these cases Mr. Lister said the operation had been first done by Dr. Hector Cameron, of Glasgow.

Schneider[1] collected nine cases thus treated, besides one of his own; in five the fracture was recent, in five old and presumably ununited. In eight good union was obtained, with a movable joint; in two the joint suppurated and ankylosis resulted.

[1] Archiv für Klin. Chirurgie, 1881, vol. xxvi.

CHAPTER XXVII.

FRACTURES OF THE BONES OF THE LEG.

According to the statistics of the London Hospital for 35 years (page 35) fractures of the leg constitute 16 per cent. of all fractures, and are second in order of frequency, those of the forearm being first, 18 per cent., those of the ribs third, 15.9 per cent. The more detailed statistics collected by Gurlt (Table I. page 34) show a total of 711 fractures, of which 464 were of the leg, that is, of both bones, 107 of the tibia, 108 of the fibula, and 32 of the malleoli. This distinction of the malleoli in the classification was made in only one-third of the cases that compose the table. The proportions in another set of statistics, quoted by Poncet,[1] are 1723 of both bones, 360 of the fibula, and 232 of the tibia. Of 2315 cases in the Pennsylvania Hospital[2] 1441 were of both bones, 437 of the tibia, and 437 of the fibula; and according to the same tables it appears that in 246 fractures of the tibia 120 were in the lower third, 81 in the middle third, and 45 in the upper third; that in 252 fractures of the fibula 210 were in the lower and 26 in the middle third. When both bones are broken the fibula is usually broken at a higher level than the tibia.

Examination of the statistics with reference to the age of the patients shows that infancy and childhood are almost exempt, and that the maximum of frequency is found between the ages of 30 and 60 years, those three decades, according to Malgaigne, furnishing equal numbers.

The varieties of fracture and the causes are those which pertain to other long bones, the different portions of the bone, however, presenting the different varieties in different degrees; and this fact, taken in connection with the great clinical differences between the fractures of the different portions, justifies, I think, a departure from the usual method of classification and description. The usual plan of describing these fractures in three groups, those involving both bones and those involving each separately, exposes to much repetition, and I have therefore followed the plan adopted in the other chapters and described them according to the position of the fracture of the tibia, as fractures of the upper end, of the shaft, and of the lower end, and have added a separate section for fractures of the fibula. The classification is not an ideal one, but its disadvantages appear to me to be less than those of others.

A. Fractures of the Upper End of the Tibia and Fibula or of the Tibia alone.—The causes of these fractures are direct or indirect violence; in the former a blow received directly upon the part, as the

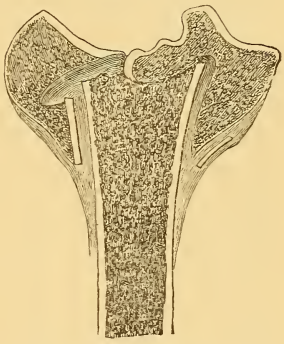
[1] Dict. de Méd. et Chir. pratiques, vol. xix. p. 496.
[2] Agnew's Surgery, vol. i. p. 981.

fall of a heavy body or the kick of a horse; in the latter a fall from a height or a twist of the limb.

A man jumped from a height of two yards and fell with his leg bent under him, fracturing the tibia close to the knee. Velpeau saw a fracture caused in a man, 67 years old, by a fall to the ground while walking; and in a case which came under my own observation, the tibia was broken just below the knee by a fall of another man from the track of the elevated railway upon the patient as he was walking in the street below.

The line of fracture may be transverse, oblique, or vertical, in the latter case passing into the joint and perhaps separating only a portion of the articular end from the shaft, as in a case under the care of Follin in which the feet of the patient became entangled in the reins as he left a wagon and he was dragged by them for some distance; the outer condyle of the tibia was broken off. Transverse fractures by direct violence, the fall of a stone, the kick of a horse, have been observed at four and seven centimetres from the articular edge. Comminuted fractures have been caused by direct violence and also (fig. 331) by falls upon the feet, the cylindrical portion of the shaft penetrating and splitting the head. Legouest observed such a result in a man who jumped from a second-story window, breaking the head of the tibia into many fragments. Verneuil saw the epiphysis separated in a child six years old whose leg had been caught between the spokes of a wheel; the joint was not opened. One or two similar cases have been reported by others.

Fig. 331.



Intra-articular fracture of the head of the tibia, with impaction and separation of the upper fragments.

In a case reported by Duplay and Marot,[1] a man 60 years old had his right leg broken by the fall upon it of a heavy stone. There was a marked angular displacement backward just below the knee which could not be reduced by traction but could be easily reduced by flexing the leg. It was due to the fact that the upper fragment was in the position of semi-flexion and remained so even when the lower part was extended. The region was immensely swollen, gangrene set in, and death took place on the thirteenth day. The autopsy showed a comminuted fracture of the upper end of the tibia extending into the joint and rupture of the popliteal vein.

Ordinarily the displacement is not so marked as in this case, and it may take place in any direction, influenced therein by the direction and the character of the fracture and by the fracturing force. If the fibula remains unbroken and is not dislocated at its upper end it aids materially in preventing any displacement that would involve shortening. To

[1] Progrès Médical, April 29, 1876.

the other usual signs of fracture, abnormal mobility and crepitation, are added loss of function, deformity appreciable by the sight or touch, and a prompt and extreme swelling of the region. If the fracture extends into the knee-joint a later swelling corresponding in position to the synomial sac is superadded; it may be merely a temporary effusion or the result of a suppurative arthritis which will seriously endanger the life and the limb of the patient.

The proximity of the main vessels and nerves to the bones increases the chances of their being torn or pressed upon by the displaced fragments, as in the following illustrative cases.

J. Bell.[1] Compound comminuted fracture of the tibia and fibula at the upper end. The leg was very much swollen, and some days afterwards it was recognized that the swelling was liquid. It was opened freely and a large quantity of blood-clot turned out, and then, as the bleeding continued from a deep artery, the limb was immediately amputated.

Nepveu[2] reported a case under the care of Verneuil. A man, 59 years old, was run over by a wagon while intoxicated and suffered a compound fracture of the leg in its upper fourth, the wound being about 8 centimetres long and the bone comminuted. Amputation was done through the lower third of the thigh, and the patient died four days afterwards. The anterior tibial artery was torn completely across, its upper end retracted into the popliteal space and its lower end to a point 6 centimetres below the opening in the interosseous ligament through which the artery passes. The vessel, which was somewhat atheromatous, appeared to have been torn at this opening.

Baudens.[3] A man was kicked by a horse and received a compound comminuted fracture of the leg in its upper third. The patient did well until about the twentieth day, when arterial hemorrhage took place. In searching for the wounded vessel a long sharp splinter was found imbedded in the soft tissues near the posterior tibial artery and was removed. Three other hemorrhages followed, one immediately after the other, and then Baudens tied the femoral artery in its upper third.

In the following case[4] the vessels appear to have been only compressed. A woman 37 years old was run over by a wagon and her left leg was broken in such a manner that the lower fragment was forced up into the hollow of the knee, leaving a marked depression just below the patella. The popliteal space was occupied by an enormous swelling which distended the skin and caused severe pain. There was shortening to the extent of four or five inches which could not be overcome. Gangrene followed, and the limb was amputated on the nineteenth day.

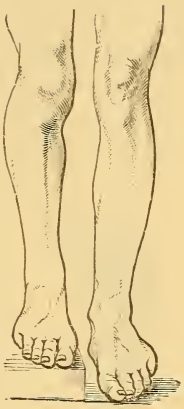
The prognosis of this injury is exceptionally serious, because of the proximity of the joint and the possibility of inflammatory complications and more or less complete loss of the functions of the knee which that involves, and also because of the exceptionally long period that is necessary to consolidation. The average period in seven cases collected by

[1] Principles of Surgery, vol. iv. p. 411.
[2] Bull. de la Société de Chirurgie, 1875, p. 369.
[3] Gazette des Hôpitaux, 1855, p. 127.
[4] Bull. de l'Acad. Roy. de Méd., 1845–46, p. 26.

Poncet was about four months. No satisfactory explanation has been given of this peculiarity.

Separation of the epiphysis may result in diminished growth of the leg, as in the case represented in figure 332, in which the injury was received at the age of eight years and the shortening two years later amounted to an inch. If the fibula does not share in the injury in like manner its growth is unchecked and its superior length must be provided for either by bowing outward of its shaft or by dislocation of its upper end upward.

Fig. 332.



Arrest of growth following injury to the upper epiphysis of the right tibia. (Bryant.)

Treatment.—Displacement, if present, must be reduced by traction or by extending or flexing the limb according to the character of the displacement, and retention effected either by permanent extension or by confinement in a fracture box or upon a posterior splint. The indications vary so greatly in this respect with the position, direction, and extent of the fracture that rules of general application cannot be laid down. If the fibula is unbroken the displacement is usually slight and the retentive apparatus will be useful mainly to immobilize and prevent lateral displacement; if the line of fracture runs obliquely into the joint, breaking off only a corner of the tibia, lateral displacement is the one to be guarded against lest a permanent genu valgum or varum should result; if there is much comminution of the upper fragment and the lines of fracture extend into the joint permanent extension will probably be necessary, together with lateral support of the fragments by pads or bandages. In any case particular attention must be given to prevent inflammation of the knee-joint, cooling lotions, the ice-bag, irrigation through a coil, according to the urgency of the conditions, and the immobilization should be absolute. After the lapse of a week or two, if the swelling has subsided and acute complications no longer threaten, a plaster bandage or plaster splint may be applied.

If the fracture is compound and communicates with the joint, and if suppuration of the joint occurs, a free outlet for the pus must be provided at the earliest moment and the case must be treated with the strictest attention to antiseptic principles. It is better to drain the joint through special openings at its sides rather than through the wound which can hardly fail to be unsuitably placed for effective drainage.

B. Fractures of the Shaft.—Fractures by direct violence may occur at any point; those by indirect violence are much more frequent at or near the junction of the lower and middle thirds than at any other point. It seems probable, as taught more especially by Gosselin, that torsion of the limb is an important factor in the production of the fracture, the twist being due either to the forcible contraction of the muscles or to the propulsion of the upper portion while the lower one is fixed by the pressure of the foot upon the ground.

The varieties of fracture common to other long bones are found here,

and in addition a special variety, the V-shaped fracture, first pointed out by Gosselin, which although occasionally found elsewhere is much more frequent in the leg. In these, which are especially frequent below the middle of the bone, the upper fragment terminates in front and on the inner side in a more or less sharp triangular point, the lower fragment presents a similar point posteriorly, and from the bottom of the depression in the lower fragment which corresponds to the first point a fissure passes spirally downward and usually runs into the ankle-joint, sometimes splitting off a superficial fragment on the posterior aspect as shown in figure 333. The extent of the fissures and the implication of the ankle-joint give this variety of fracture an especial importance.

Fig. 333.

V-shaped fracture.

It is very rare for the tibia alone to be broken when the fracture is by indirect violence, for the force continues to act, if only for a moment, and breaks the weaker fibula all the more easily, and usually at a higher point than the tibia.

The subcutaneous position of the tibia throughout its entire length exposes its fractures greatly to the chance of becoming compound either by the direct action of the causative violence when the fracture is direct, or by the perforation of the skin by the end of one of the fragments, usually the upper one, when the fracture is indirect.

The displacements show the usual varieties, but the most common and important is the projection of the lower end of the upper fragment when it terminates in a point, as it usually does, upon the anterior and inner face of the bone. The contraction of the muscles draws the lower fragment upward, and this forces the end of the upper one forward since the line of fracture is oblique from below upward and backward, and, in addition, the muscles of the calf tend to draw the heel backward and create an angular displacement which, of course, exaggerates the projection of the fragment. If the limb is raised and the knee kept partly flexed the tension of the quadriceps femoris acts in favor of the same displacement.

In addition to the usual symptoms of crepitation, abnormal mobility, pain, and loss of function, there is also the irregularity in the outline of the subcutaneous portion of the tibia which may often be recognized by passing the finger along it. It is not always possible to say whether or not the fibula is broken as well as the tibia without making a more severe and painful examination than the need of the information will justify. When both bones are broken the mobility is usually much greater than when the tibia alone is broken, and by making gentle pressure with the finger along the line of the fibula the point of fracture can usually be determined.

Beside the frequent complication of a communicating wound of the skin, and the comminution which is so often the result of direct violence, injury to the principal vessels is occasionally met with. Nepveu,[1] in a

[1] Bulletins de la Société de Chirurgie, 1875, p. 365.

very complete and elaborate paper read before the Surgical Society of Paris, collected more than fifty cases, among which are found examples of injury to both tibials, the peroneal, and the nutrient artery of the tibia. Injury to the tibial or peroneal nerves seems to be much more rare. The following cases are quoted in illustration.

Case II.—Man 41 years old, oblique fracture with lacerated wound of the integuments, and rupture of the muscles caused by the passage of a heavy wagon. Spasms, trismus, opistothonos, and gangrene of the wound. Amputation on the thirteenth day, and death on the next. The autopsy showed that a splinter had penetrated the sheath of the anterior tibial artery and the substance of the peroneal nerve, there was an extensive neuritis, and a splintered fracture of the tibia.

Case I.—Farabœuf presented to the Société Anatomique (Bulletins, 1866, p. 6) the specimens of a V-shaped fracture of the leg that terminated fatally on the seventh day. There was incomplete rupture of the posterior tibial artery, the vessel resting upon the point of the fragment. The inner and middle coats alone were torn.

Case X.—A lad 16 years old was overthrown by a falling tree and received a comminuted fracture of the right tibia at its middle, an oblique fracture of the fibula, and a contused wound on the anterior surface of the tibia three inches above the ankle, with profuse hemorrhage from the anterior tibial artery which recurred when the provisional dressing was removed. The wound was enlarged, the splinters removed, and the artery tied. The patient made a slow recovery, after fever, profuse suppuration. and necrosis of part of the tibia.

Case XXXIX.—A man 55 years old fell and broke both bones of the leg in the middle third, the upper fragment projected under the skin and there was a manifest tendency to return of the displacement after reduction. About the fifteenth day he complained of pain in the calf, and a few days later a firm bluish swelling appeared at the middle of the leg. Amputation was done, and an aneurism of the peroneal artery found. The sharp fragments of the fibula had lacerated the vessel very irregularly.

Case XLVI.—Man, overthrown by a wagon, simple fracture of both bones, removal of the dressings after the sixth week. Six weeks afterwards the patient noticed that a large tumor had formed at the outer part of the limb, beginning two or three finger-breadths above the external malleolus, extending around the posterior part of the leg, and ending at the upper part of the inner aspect. It was fluctuating, did not pulsate, and its size was not modified by pressure above or below. At its lower and outer portion could be heard a single, rough, harsh murmur, and three finger-breadths above it in a circumscribed space corresponding to the point of fracture of the tibia were two distinct murmurs, the first stronger than the second. A fortnight later the tumor became very painful at its upper and inner part and was punctured. Hemorrhages followed and the limb was amputated.

The autopsy showed a very oblique fracture of the tibia at the junction of the middle and lower thirds. The hemorrhage came from numerous branches of the nutrient artery of the tibia opening on the surface of the fragment.

A simple fracture without persistent displacement will usually become firmly consolidated in six weeks; but in the comminuted ones and in those that are oblique with persistent displacement the callus remains weak much longer. Complete recovery is long delayed by rigidity at the ankle, tenderness of the skin, feebleness of the circulation, and neuralgic pains which are more common after fractures of the leg than after those of other long bones. In the old and rheumatic this delay is especially prolonged.

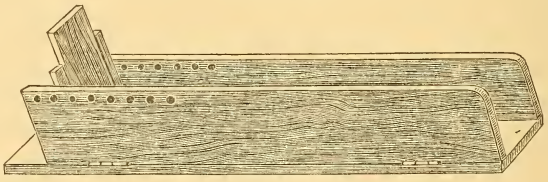
If the suppuration becomes free after a compound fracture it is probable that complete recovery will be postponed for even a much longer time, and that sinuses leading down to bare or necrosed bone will remain open for many months or will reopen at intervals. On the other hand, the subcutaneous position of the tibia makes it easier to drain the cavity of the fracture thoroughly and to remove splinters, and thus makes the danger to life less than after compound fracture of bones that are more deeply placed.

Treatment.—Reduction of the displacement can generally be made by extension at the foot and counter-extension at the knee, this joint being slightly flexed to relax the muscles of the calf. In the more difficult cases in which spasm of the muscles opposes reduction, compression of the femoral artery for a few minutes, as suggested by Broca, has sometimes proved useful in my experience. In a small proportion of cases complete reduction is impossible, probably because of the interposition of a muscular bundle between the fragments.

Maintenance of the reduction depends largely upon the character of the fracture; when this is nearly transverse and toothed, the displacement is unlikely to recur; but when it is oblique the difficulties of complete retention are extreme. The segment of the limb below the fracture is too short to permit extension through strips of adhesive plaster, as in fracture of the thigh, and the surgeon has to depend upon some form of lateral splints or an immovable dressing, neither of which will certainly prevent shortening, although the amount may be so slight as to be without practical importance.

One of the simplest and most popular methods is the fracture box (fig. 334) with hinged foot-piece and sides. The foot-piece should be

Fig. 334.



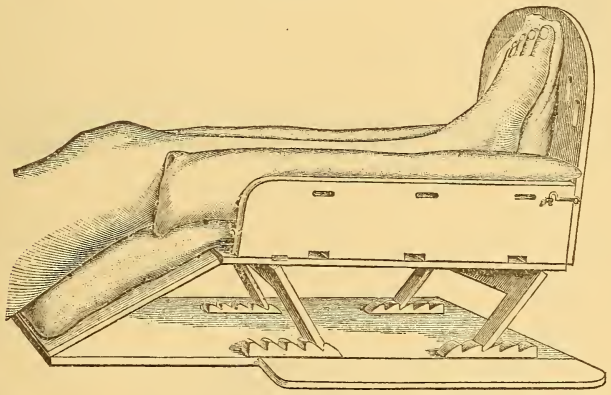
Fracture box.

movable so that it can be adjusted to the length of the limb, and the lower ends of the side-pieces should be perforated for the passage of a rod, against which the foot-piece can rest, and of cords by which it can be secured. When it is brought into use, the bottom of the box is first covered with a layer of oakum or cotton, the foot is suspended from the

foot-piece by a broad piece of adhesive plaster extending from about the middle of the calf, under the heel, and along the sole, and tacked to the top of the foot-piece in such a way that the back of the heel does not rest upon the bottom of the box (I have sometimes used, in compound fractures, a long posterior plaster of Paris splint in place of this strip of adhesive plaster, in order to get additional solidity). The foot is then made fast to the foot-piece by a roller bandage, the turns of which pass across the dorsum of the foot, and behind the ankle and heel, and through vertical notches or slits in the foot-piece. Extension and counter-extension are then made at the foot and knee, the oakum adjusted under the limb to secure even support throughout its length, and the hinged sides of the box turned up and made fast by straps or bands tied about them. Oakum should be packed in between the limb and the sides of the box, and cushions or pads placed along its anterior aspect, and bound down by the straps which hold up the sides of the box.

If the extended position of the knee is trying to the patient, the box may be swung from a cradle or a higher support, or Petit's fracture box (fig. 335) may be used. One of the advantages of having the knee

Fig. 335.



Petit's fracture box.

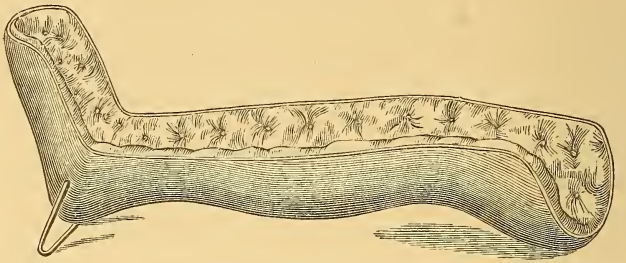
flexed, is that this position opposes the occurrence of rotatory displacement, an accident which may easily escape notice when the limb is straight. The upper segment with the thigh rotates outward, while the foot remains fixed, and if the fragments unite in this position the patient will walk with the toes turned in. If the surgeon is on the watch for this displacement it will hardly escape his notice, since the relative position of the patella and foot shows it very clearly.

Wire troughs (fig. 336) are in general use in France as substitutes for fracture boxes, and afford equal facilities for inspection of the limb without moving or disturbing it.

The general practice in the hospitals in New York is to place the limb in a fracture box for a few days, and apply lead and opium; and then after the swelling has subsided to put on an immovable dressing of plaster of Paris, and let the patient get up.

Plaster of Paris may be applied as a complete encasement (fig. 337), or in the form of the Bavarian splint (fig. 338), or as a posterior splint

Fig. 336.



Bonnet's gutter for the leg.

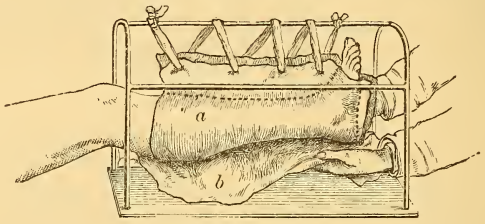
(fig. 339) with or without one or two lateral ones. I am rather partial to the latter because they can be so made as to leave the region of the

Fig. 337.

Encasement of the leg in plaster of Paris.

fracture open to inspection. The posterior splint should be thick and heavy, ten or twelve thicknesses of crinoline or cheese-cloth, and should

Fig. 338.



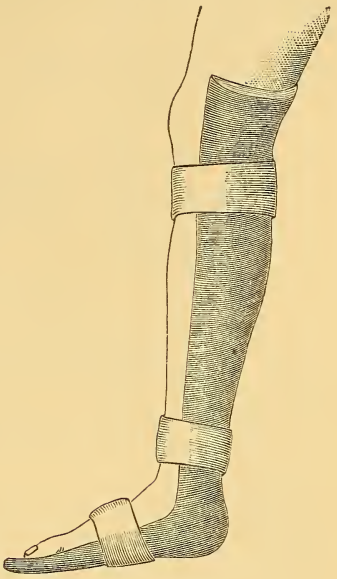
The Bavarian splint.

reach from a little above the toes to the middle third of the thigh. The lateral splint should be of about the same length, and, starting from the outer side of the foot just in front of the ankle, should be wrapped around the dorsum, inner side, and sole, and then be carried up the outer side of the leg. The splints should be secured to the limb with a few turns of a roller bandage until after they have hardened, when strips of adhesive plaster may be substituted. These splints may be used while the case is still recent, and so may the Bavarian splint, but

I think it is better to defer complete encasement in plaster until after the primary swelling has subsided.

Many plans have been suggested by which permanent extension may be made upon the limb to overcome shortening in those cases in which this indication becomes a prominent one; and in most of them the counter-extension also is provided by the apparatus, and not by the weight of the body as in the treatment of fracture of the thigh. If a Volkmann's sliding foot-rest were used instead of a fracture box, or if the fracture box were placed upon a similar support, it would be sufficient to attach the weight to the box if it did not need to be very heavy or its use to be long continued. Otherwise the attachment must be by means of strips of adhesive plaster applied to the lower part of the leg in the usual manner.

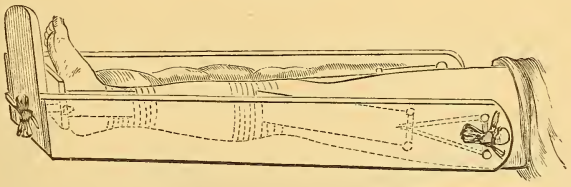
Fig. 339.



Posterior gypsum splint or gutter.

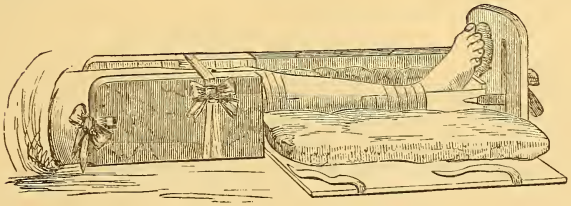
Figures 340 and 341 show Dr. Neill's apparatus, and figure 342 a somewhat similar one often used in the Massachusetts General Hospital when the fracture is in the middle third.[1]

Fig. 340.



Dr. Neill's dressing.

Fig. 341.



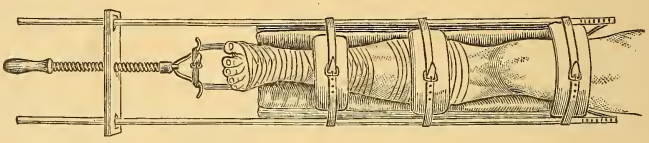
Dr. Neill's dressing. Compound fracture.

The plaster strips for extension, in the latter, "reach from the top of the lower bandage to the spreader attached to the screw, and the counter-

[1] The Medical News, April 8, 1882, p. 377.

extension from the lower edge of the upper bandage to the top of the splints, where they are fastened." Pads are placed between the side-splints and the limb to prevent lateral displacement, and the whole bound together with straps.

Fig. 342.



Continuous extension in fracture of the leg.

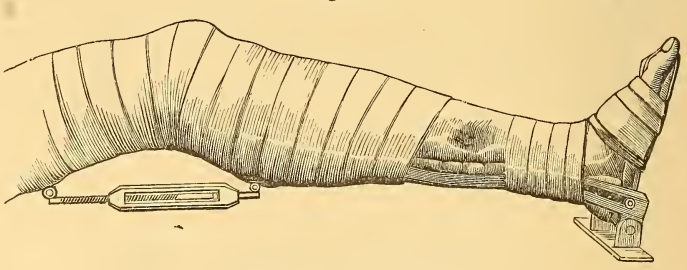
I have no experience with either method, but should doubt the efficiency of extension made by two sets of plaster strips with only a short interval between them. I should fear that the force of the traction would be exhausted upon the intermediate strip of skin, and that the fragments would be left free to override to as great an extent as under other dressings.

Lateral splints made of binders' board, or other material that can be moulded to the leg and foot, are sometimes used, especially when the fracture is in the lower third. They should be well padded and openings should be made at the points corresponding to the malleoli.

The bivalve cushion (page 161) is highly recommended for use in simple cases or in emergencies.

In Liston's splint (fig. 343) the counter-extension is provided by a thigh-piece adjustable at any desired angle to the leg-piece; the foot-

Fig. 343.



Liston's double inclined plane.

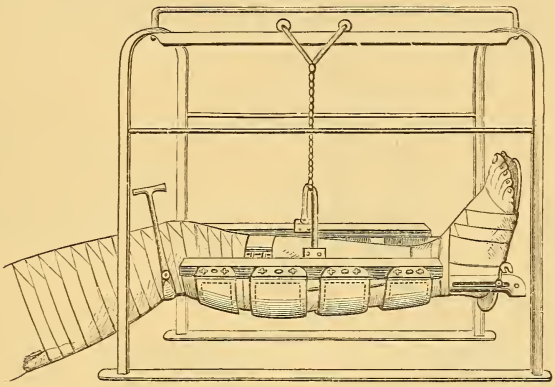
piece also can be adjusted according to the length of the leg. The splint is suitably padded or lined, the foot made fast to the foot piece by bandaging, and then the thigh to the upper part in like manner, while extension is made with the hands. It is not probable that this splint will protect against overriding if there is any marked tendency thereto.

Figure 344 shows a similar splint with Salter's suspending apparatus.

Malgaigne's point (figs. 345 and 346) was designed for use in cases in which the tendency of the lower end of the upper fragment to displacement forward could not be controlled by splints. It consists of a curved metal band fastened over the limb by a strap that passes behind

the posterior splint. It is placed a little above the fracture, and the central pin, which has a sharp point, is screwed down through the skin

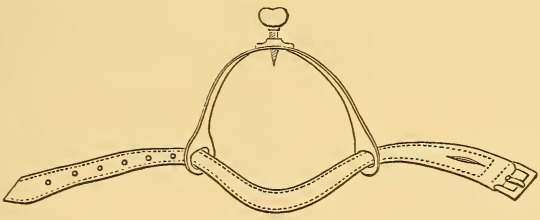
Fig. 344.



McIntyre's splint and Salter's swing.

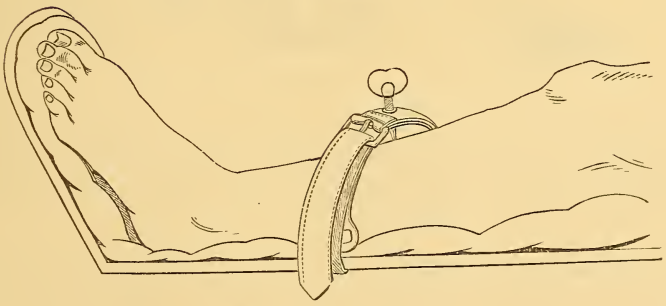
and made to press directly upon the upper fragment and hold it in place. Most surgeons, and probably all patients, would hesitate to use this

Fig. 345.



Malgaigne's point.

Fig. 346.



Malgaigne's point applied.

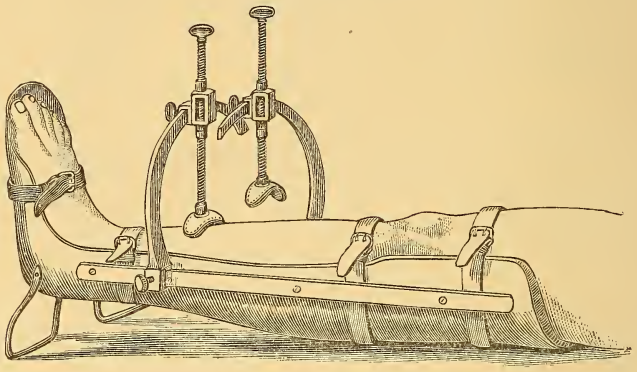
means, and in a few cases its use has caused much pain, and in others erysipelas. In a thesis by Rioms,[1] 36 cases treated in this manner are

[1] Dict. de Méd. et Chir. prat., vol. xix. p. 521.

reported, 10 of which were compound fractures. The instrument maintained the reduction in every case, and apparently it was not used in any of them until after other means had proved ineffectual.

Anger's apparatus (fig. 347) seeks to accomplish the same result by pressure and to avoid injury to the skin by shifting the points of pressure as often as may be necessary.

Fig. 347.

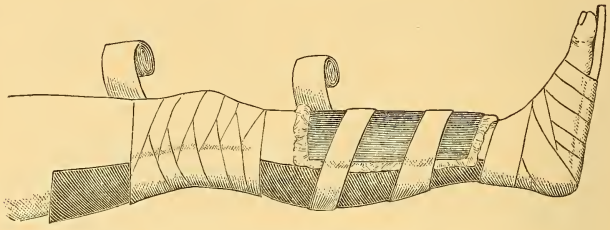


Anger's apparatus for alternate pressure.

Division of the tendo Achillis has been resorted to in some cases.

When the fracture is compound, the limb may be placed upon a posterior splint (fig. 348) or suspended, as in fig. 349, the anterior splint

Fig. 348.

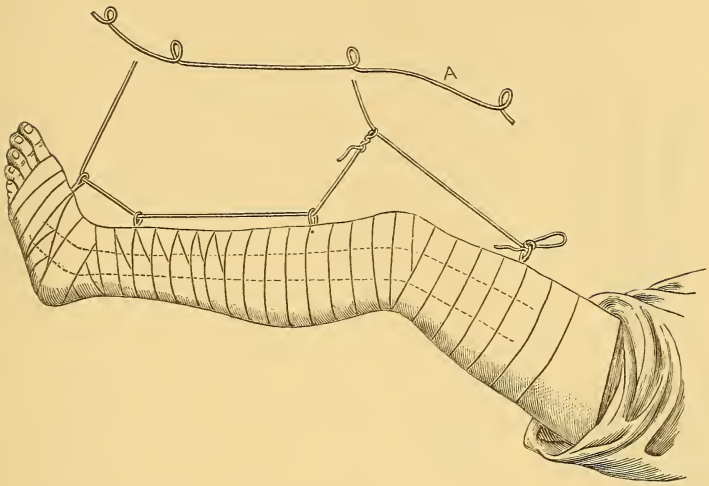


Compound fracture. Lister dressing and plaster splint.

being placed outside the dressings of the wound. If the wound suppurates and the pus burrows it will probably become necessary to use the interrupted or bracketed plaster splints (fig. 350) so as to obtain the necessary space for the dressing and counter-openings.

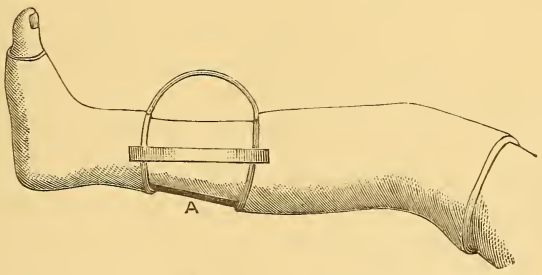
C. Fractures at the Lower End of the Leg.—In this group I place some exceptional fractures of both bones, in which the lower end of the tibia is crushed or splintered, caused by a fall from a height upon the feet, and the numerous fractures of one or both bones at or near the joint, "malleolar fracture," caused by forcible inversion or eversion of the foot, fractures which present several anatomical varieties, of which the more common is known as Pott's fracture.

Fig. 349.



Anterior and posterior plaster splints. *A* is a wire bent into loops for the purpose of suspension.

Fig. 350.



Interrupted plaster dressing. *A*, the straight posterior iron splint.

There is but little to be said concerning the first, and I shall merely quote briefly the descriptions of a few reported cases. One was reported by Chassaignac and Richelot, the translators into French of Sir Astley Cooper's Fractures and Dislocations. The foot was displaced inward and seemed to be shortened; the fibula was broken and its malleolus displaced backward; reduction was impossible. At the autopsy a fragment comprising the posterior half of the articular surface of the tibia was found broken off and displaced backward about an inch, but still resting on the astragalus. The ligaments were intact.

In another case also reported by Chassaignac, in 1858, the fracture was caused by a fall from the third floor; the limb was amputated two months afterwards. The tibia was broken four finger-breadths above the joint and the lower portion was split into four secondary fragments by the penetration into it of the upper one. The fibula was the seat of a double fracture also in the lower third; the intermediate piece was four centimetres long, necrosed, and imbedded in the callus.

A third is a specimen in the museum at Val-de-Grâce described by Poncet.[1] Figure 351 shows the direction of the lines of fracture, the lower end of the tibia having been broken into six fragments.

Fig. 351.

Comminuted fracture of the lower portion of the leg.

Similar cases are described by Cooper and Malgaigne.

No rules of treatment can be formulated in advance; each case must be treated in accordance with its special indications. If the attempt is made to preserve the limb, especial attention should be paid to the position of the foot in the splints in order that, if ankylosis of the ankle-joint follows, the sole may rest squarely on the ground in walking. Even a slight deviation, either to one side or from a right angle in the antero-posterior plane, is a source of much inconvenience.

The fractures of the malleoli and of the tibia and fibula just above the ankle that are produced by forcible inversion or eversion of the foot with rotation of the toes to the inner or outer side present several varieties which differ widely in the extent and position of the lines of fracture, but which can be grouped advantageously according to their supposed mode of production. The mechanism of these fractures has been discussed for more than a century and many explanations and theories concerning it have been suggested the discussion of which here would not be profitable, and I shall follow the etiological classification and describe: 1st fractures by inversion and adduction of the foot, and 2d fractures by eversion and abduction of the foot. The very complete experimental and clinical study of the subject made by Tillaux[2] shows that all these fractures can be produced in these ways, and the classification is not only simple and justified by experiment but it also corresponds with important clinical differences.

Figure 352 may serve to recall some of the anatomical peculiarities of the ankle-joint which are principally concerned in the production of these fractures, such as the strong lateral ligaments and their insertions upon the malleoli, the inferior interosseous ligament binding the tibia and fibula together, and the astragalus set in between the malleoli as in a mortise. The only motion which this joint permits normally is in the direction of flexion and extension, except that when the foot is extended (plantar flexion) a slight degree of rotation about a vertical axis is possible, an exception which does not affect the correctness of the statement that the existence of lateral mobility in the joint is a proof that it has been injured or diseased.

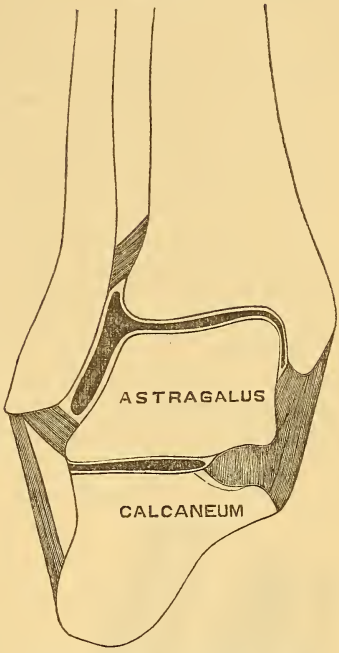
1. *Fractures by Inversion and Adduction of the Foot.*—In this movement the foot turns so that if the individual is upright its outer border rests upon

[1] Dict. de Med. et Chir. prat., vol. xix. p. 531.

[2] Bull. de l'Academie de Médecine, 1872, pp. 339 and 819, and Anatomie topographique, p. 1172.

the ground, the sole is directed inward ("tibial-flexion"), and the toes are also turned inward. The external lateral ligaments are put upon the stretch and if they resist the strain, if a simple sprain is not produced, the fibula breaks either above or below the lower tibio-fibular articulation.[1] If it breaks below, if the fracture is of the malleolus, it may be at its apex or, more commonly according to Tillaux, at its base; the line of fracture is transverse and the periosteum untorn, there is no displacement of the fragment or of the foot, and the only sign of fracture is the localized pain or pressure at its seat. The inner side of the ankle is uninjured. If, however, the action is continued its force is transmitted through the astragalus to the internal malleolus, the tip of which may then be broken off by the direct pressure upon it. Tillaux produced this secondary fracture several times experimentally, and thinks he has seen it upon the living, the evidence being the existence of a fixed pain at the base of the internal malleolus and sometimes a slight groove recognizable by the finger at a point corresponding to the seat of the pain.

Fig. 352.



Vertical section through the malleoli.

Sir Astley Cooper[2] describes under the title of "dislocation of the tibia outwards" an oblique fracture of the internal malleolus (fig. 353), and speaks of it as the most dangerous of the three dislocations because produced by greater violence and attended with more injury to the soft parts and bones than either of the others. The malleolus alone may be broken off or a part of the articular surface may remain attached to it; the astragalus is sometimes fractured and the lower portion of the fibula broken into several splinters, or the external lateral ligament ruptured. The lesions, as described by him in this case, may be considered an exaggeration of those of the preceding paragraph, due to greater violence and to lateral bodily displacement of the foot, rather than to its inversion.

Fig. 353.

Fracture of the internal malleolus.

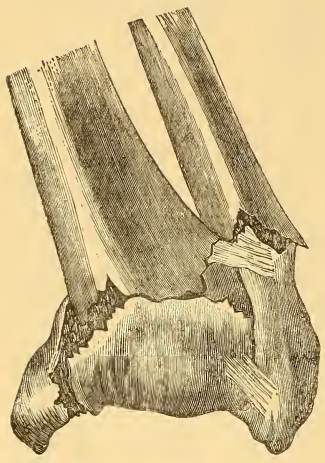
The fibula may break above the point where it rests against the tibia, that is, the tip of its malleolus is drawn inward by the forced movement of the foot, and the shaft of the bone is correspondingly sprung or tilted outward. The usual seat of the fracture in this case is one and a half inches above the tip of the malleolus. This fracture must not be confounded with the common one, to be subsequently

[1] For a possible alternative see Fractures of the Calcaneum, p. 590.
[2] Loc. cit., p. 230.

described, in which the foot is twisted outward, the internal lateral ligament torn or the internal malleolus broken, and the fibula broken at a point somewhat higher up, about two and a half inches above its tip. In the fracture by inversion the symptoms are very different, for the region of the internal malleolus and deltoid ligament is entirely free of pain (except in the rare contingency of fracture of the internal malleolus by pressure from within the joint outward), the foot is not displaced outward, and there is very little, if any, lateral mobility in the joint. The following case will illustrate the fracture, which is not a common one.

K., 49 years old, was admitted to Bellevue Hospital February, 1882. He said that while quarreling with a man he twisted his foot inward, felt pain at the ankle, and found himself disabled. There was no displacement of the foot, and no tenderness and no ecchymosis on the inner side of the ankle. There was localized pain on pressure and distinct crepitus 1½ inches above the tip of the external malleolus, and by pressing the latter in toward the foot with one finger the upper end of the lower fragment could be felt to tilt outward; by alternate pressure on its ends the fragment could be rocked upon the tibia. The line of fracture was oblique from above downward and inward.

Fig. 354.



Supra-malleolar fracture with crushing. (Malgaigne.)

If the force continues to act after the fibula has broken above the inferior interosseous ligament, the tibia may break transversely just above its lower articular surface. Tillaux speaks of this as a fracture that had not been described before, but it seems to be the same as some described by Malgaigne as "supra-malleolar fractures," and of which he gives fig. 354 as an example. Tillaux produced this fracture several times experimentally, and claims to have recognized it also upon the living; I remember to have seen a case in his wards in 1874 in which he made this diagnosis, basing it on the existence of a limited line of pain on pressure crossing the internal malleolus two centimetres above its point and continuing along the front of the tibia just above its articular edge, on a painful point six centimetres above the tip of the external malleolus, absence of deformity, and slight mobility of the foot from behind forward with loud crepitus.

He reports[1] a case which he considers a most striking confirmation of his theory of the mechanism of this fracture by inversion, one in which dislocation of the upper end of the fibula took the place of fracture of this bone. A man 38 years old had fallen with his leg caught under him. Tillaux recognized a transverse fracture of the tibia three finger-breadths above the tip of the malleolus and a diastasis of the upper end of the fibula. There was but little displacement at the fracture, the

[1] Anatomie topographique, p. 1174.

lower fragment had slipped forward, and the extensor tendons were slightly raised and stretched. The upper end of the fibula moved very freely on pressure and gave a loud cartilaginous crepitus.

The diagnosis is made by attention to the symptoms already mentioned; the principal ones, in fracture at or just above the base of the malleolus, are the abnormal mobility of the fragment recognized by pressure with the end of the finger, the localized pain, and the absence of displacement of the foot and of symptoms on the inner side of the ankle except when the tip of the internal malleolus is also cracked.

The prognosis is relatively favorable because of the absence of displacement, the limited extent of the injury, and, in some cases, the non-implication of the joint. In the variety last described, that in which the fracture crosses the tibia, the prognosis may be made more grave by the splitting of the articular fragment.

The treatment consists in simple immobilization in a good position in cases in which the fracture is limited to the fibula or to the fibula and internal malleolus, preferably by a plaster splint or dressing. I have treated one or two cases by simple rest in bed, with cooling lotions or pressure to reduce swelling, and the result has been satisfactory. In the supra-malleolar variety displacement must be corrected if present and its recurrence guarded against.

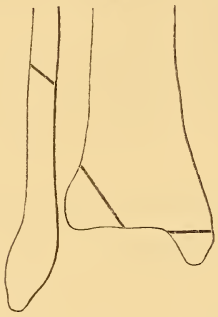
2. *Fractures by Eversion and Abduction of the Foot.*—In this movement the foot turns toward the outer side (fibular flexion), and at the same time the toes are turned outward. The internal lateral ligament is put upon the stretch and either it is torn off the malleolus or calcaneum, or the malleolus is broken transversely at its base by avulsion. The force continuing, the astragalus is pressed against the external malleolus and either forces it directly outward with rupture of the inferior interosseous ligament and diastasis of the lower tibio-fibular articulation, or by forcing it outward produces first a compensatory curving inward of the shaft of the fibula followed by its fracture at about 2½ inches above the tip of the malleolus and then by the rupture of the inferior interosseous ligament or the tearing off of the portion of the tibia to which this ligament is attached. In a typical and complete case there are three fragments: the internal malleolus, the external malleolus and adjoining portion of the shaft of the fibula, and the lower outer articular border or corner of the tibia as shown diagrammatically in figure 355. This is the common Pott's fracture, the capital feature of which, with reference to the prognosis, is the separation of the tibia and fibula, the widening of the mortise in which the astragalus lies. It is more common, I think, for the internal malleolus to break than for the internal lateral ligament to tear, and Tillaux says that in his experiments he always found that the inferior interosseous ligament had resisted and had torn off the portion of the tibia to which it was attached.

In extreme cases the broken end of the tibia may be forced through the skin, making the fracture a compound one and opening the joint, or the astragalus may be forced up between the tibia and fibula.

The symptoms are the displacement of the foot to the outer side (fig. 356) with consequent prominence of the internal malleolus, eversion of the sole of the foot usually, sometimes a depression, "axe-cut," on

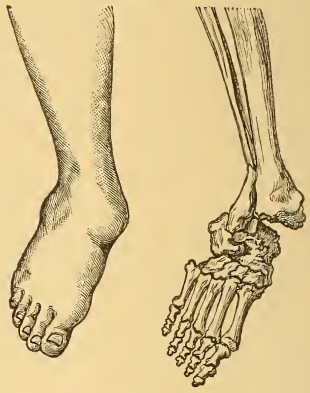
the outer side of the leg at the point where the fibula is broken. Extensive ecchymoses below the ankle on both sides, pain or pressure at or below the internal malleolus and over the fibula at a point two or three inches above the tip of the external malleolus, lateral mobility in the ankle-joint.

Fig. 355.



The usual three lines of fracture in Pott's fracture at the ankle

Fig. 356.



Displacement in Pott's fracture.

The prognosis in simple fractures without displacement or in those in which reduction can be made and maintained is good, that is it may be expected that consolidation will take place in from four to six weeks, that the stiffness will gradually disappear, and that the joint will recover its functions in great part or entirely. But if the displacement is not thoroughly reduced the stability of the joint is lost, the foot lies outside the axis of the leg, and the weight of the body tends to evert it and to strain the internal lateral ligament. The disability is then great. An extreme degree of this deformity is shown in figures 357 and 358.

If the fracture is compound the prognosis is much more grave, and it is not uncommon to see the case end in ankylosis or amputation.

The treatment consists in the complete reduction of the displacement and the maintenance of the foot in such a position that the displacement cannot recur in even the slightest degree. The success of the treatment depends upon the thoroughness with which this indication is met. It is not sufficient to bring the foot back to the axis of the limb, it must be inverted and held so. It is essential that the malleoli shall again embrace the astragalus snugly and that the internal lateral ligament shall not be lengthened if it has been torn, or that the internal malleolus shall fail of close union if it has been broken.

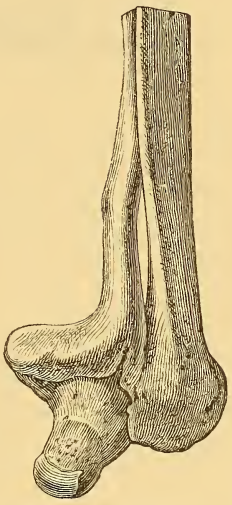
If there is much swelling, ecchymosis, and tenderness, if blebs have formed, I prefer to postpone the application of a permanent dressing for a week or ten days, keeping the limb meanwhile in a fracture box, or upon a posterior plaster splint in good position, that is, with the sole inverted and the heel well supported, and applying lead and opium constantly. After the swelling has subsided I apply a plaster of Paris bandage from the toes nearly to the knee and make it especially

thick at the ankle. In addition to the usual circular turns I pass the bandage several times like a stirrup from one side of the leg under the instep to the other side to aid in keeping the foot inverted until the plaster has hardened, and secure them with other circular turns.

Fig. 357.

Vicious union after fracture of the fibula.

Fig. 358.



Vicious union after fracture of the fibula 2½ inches above the tip of the malleolus.

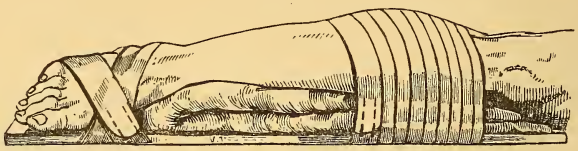
During the application of the bandage the foot must be kept strongly pressed to the inner side by one hand pressed against the outer side of the heel and instep below the malleolus, and the other making counter-pressure on the inner side of the tibia just above the ankle. The pressure on the foot must be made behind the medio-tarsal joint; pressure on the front part of the foot may deceive by simply rotating the toes inward while the tarsus remains displaced to the outer side or everted.

If, for any reason, I wish to keep the ankle exposed to view, as in cases in which the tendency to displacement is marked, I use posterior and lateral plaster splints made usually of eight or ten thicknesses of crinoline soaked in plaster cream. The posterior splint extends from the toes to the knee, and the lateral one is either single and extends from the dorsum of the foot around the sole and up the inner side of the leg, or it is double and passes under the sole like a stirrup. A few turns of a roller bandage will hold them in place until they harden. Such a bandage will usually immobilize the limb effectually.

A dressing which has been much used in the past, but which has now

given place to the immovable dressings is Dupuytren's splint (fig. 359). It may be found useful during the first week or ten days before the application of the permanent dressing. It consists of a straight wooden lateral splint somewhat longer than the leg, and four or five inches wide,

Fig. 359.



Dupuytren's splint.

and a long thick pad. The splint is placed on the inner side of the leg, with the pad between and ending just above the ankle, and is secured below the knee with a few turns of a roller bandage. The foot is then pressed inward and secured by a bandage, the turns of which pass under and behind the heel and across the dorsum of the foot and the outer side of the ankle not higher than the base of the malleolus. It must be remembered that the object is to press the foot forward and inward, and to invert its sole, and to press the external malleolus against the tibia.

It is very easy to be deceived with regard to the relative positions of the astragalus, tibia, and external malleolus after this accident, especially if the surgeon looks only at the front part of the foot. I quote the following case as an example of this deception, of the extreme displacement that may follow fracture even by slight violence, and of the occasional difficulty of reduction. It was reported by Polaillon.[1]

A woman 58 years old, was admitted to La Pitie, Feb. 11, 1880 ; the previous evening while drawing off her boot with her hands she had "turned" her foot outward. There was found a fracture of the fibula two finger-breadths above the malleolus, very marked prominence of the internal malleolus, and dislocation of the foot to the outer side. Chloroform was given and reduction attempted, but without success, and then the limb was placed on Dupuytren's splint with the hope of making reduction progressively. Ten days afterwards the dressing was removed because of the pain, and because the skin covering the internal malleolus had become gangrenous ; "at this time the foot showed no longer any tendency to be displaced outward, and it seemed as if the reduction had made notable progress."

The slough fell, the wound was dressed antiseptically, but the patient died of erysipelas four months after the accident.

The specimen shows an oblique fracture of the fibula beginning five centimetres above the tip of the malleolus, passing downward and forward, and terminating two centimetres above it. The malleolus had preserved its relations with the outer side of the astragalus and was displaced outward so far that the astragalus had entirely left the articular surface of the tibia, and lay on its outer side in contact with the upper fragment of the fibula.

[1] Bull. de la Société de Chirurgié, 1880, p. 436.

In his comments on the case he says, "the improvement which I obtained in the form of the limb by Dupuytren's dressing, was due to a sort of turn of the foot inward. It was such that the foot seemed to have been brought back into the axis of the leg, and I had no doubt but that the patient would be able to walk very well when cured. But the specimen shows that this reduction was only apparent."

The following case is interesting because of the success of the attempt to correct deformity due to union in a faulty position. It was reported by Le Dentu.[1]

A man 55 years old, broke his right leg, Dec. 7, 1879. When first seen by Le Dentu, March, 1880, there was a sharp angular displacement eight centimetres above the external malleolus; the foot, deviating sharply to the outer side, made an angle of about 45° with the leg. The internal malleolus was displaced with the foot, the lower end of the tibia was very prominent above it, and the skin at that point was adherent to the bone and livid, and threatened to ulcerate.

The patient was chloroformed March 22d, and the bones refractured with a modified Collin's osteoclast, an instrument composed of a bar carrying three adjustable arms, of which the upper one rested against the outer side of the leg, the middle one against the inner side just above the malleolus, and the third against the outer surface of the foot and ankle. The middle one faced outward and was used to make the pressure, the other two faced in the opposite direction, and furnished the support or counter-pressure. The refracture was effected easily, and the displacement entirely corrected; the limb was placed in a solid plaster splint, and kept there for six weeks. There still remained a slight deviation outward, but the result was satisfactory, the sole of the foot rested squarely on the ground, and the patient, at the time of the report, three months after the operation, could use the limb.

Dr. Fenger,[2] of Chicago, has got good results in cases in which consolidation had taken place with outward deviation of the foot by "supra-malleolar osteotomy." He exposed the tibia two inches above the internal malleolus, and removed a wedge-shaped piece the base of which, one inch in breadth, was on the inner surface of the bone, the apex at the outer surface; the foot could then be brought back into the line of the long axis of the leg after fracturing the fibula. In his second case he perforated the fibula several times with a drill to facilitate its fracture. The results of his operations appear to have been satisfactory, although full details of the condition of the joint are not given.

I saw a similar operation done by Dr. Thos. T. Sabine, at St. Luke's Hospital, New York, in January, 1881, to relieve the same disability. He divided each bone about an inch above the base of the malleolus with a chisel through separate incisions, and was then able to bring the foot into the axis of the leg without removing a wedge of bone. The operation was done antiseptically, and the patient made a good recovery.

This operation meets only one indication, it brings the foot back into line but it does not correct the separation of the malleoli, and it changes

[1] Bull. de la Société de Chirurgié, 1880, p. 419.
[2] Medical News, April 15, 1882, p. 398.

the direction of the articular surface of the tibia so that it faces inward instead of being horizontal.

Excision of the ankle, partial or complete, to overcome the disability due to consolidation of the fracture in a faulty position, is done quite frequently by the French surgeons. The details of the operation vary according to circumstances, but in all the entire articular surface of the tibia and usually the upper articular surface of the astragalus are removed. Verneuil removes the external malleolus also, and resects the tendons of the peroneal muscles and tibialis posticus, to prevent eversion of the foot. Polaillon and Terrillon leave the external malleolus in place as a support during repair, but break the shaft of the fibula with a chisel at the seat of the original fracture as a first step in the operation. This makes it easy to turn out and excise the lower end of the tibia through a vertical incision on the inner side. Ankylosis is sought for, and the result appears to be satisfactory.[1]

D. Fractures of the Fibula.—In this section are included only the less common fractures, those occurring above the lower third, and not due to forcible twisting of the foot. The fracture which occurs so frequently in the lower third in connection with rupture of the internal lateral ligament or fracture of the internal malleolus has been described in the preceding section.

Fractures of the upper end of the fibula may be produced by direct violence, by muscular action (contraction of the biceps), or by violent bending of the leg to the inner side by which the external lateral ligament is put upon the stretch and the head of the fibula, to which it is attached, torn off. The reported cases are not very numerous.

In April, 1882, a child, about two years old, was run over by a street car and brought to the Presbyterian Hospital. In addition to other injuries which were promptly fatal, there was a lacerated wound on the outer side of the right leg exposing the upper end of the fibula and opening the knee-joint. The epiphysis of the fibula was completely detached from the shaft and from the tibia and remained attached to the external lateral ligament and the tendon of the biceps; there was also an incomplete fracture of the shaft of the fibula three-fourths of an inch below the epiphyseal line, and the intermediate portion was denuded of its periosteum which remained attached to the epiphysis. I showed the specimen to the N. Y. Surgical Society April, 1882.

Gurlt[2] quotes three cases in which the head of the fibula was broken off by the forcible contraction of the biceps; one of them is quoted in Chapter IV., p. 96.

Duplay[3] reported two cases in which the fracture was caused by violent bending of the leg to the inner side. The patients were men, the one 48 and the other 60 years old, who were caught in machinery and whirled around, their bodies and limbs striking against a neighboring wall. At the upper end of the fibula could be felt a bony tumor as large

[1] Bull. de la Société de Chirurgie, 1882, pp. 61, 65, 71, 87, 430.
[2] Lehre der Knochenbrüchen, vol. i. p. 243.
[3] Bull. de la Société de Chirurgie, 1880, p. 218.

as a large hazel-nut, very movable laterally, rising when the leg was flexed, and descending when it was extended. It was directly continuous with the tendon of the biceps, and below it was a deep depression that would admit the thumb. There was free lateral mobility at the knee, and the tibia could be dislocated inward. Numerous contusions on the outer side of the leg and foot showed where the violence had been received, and one of the patients was able to describe how the leg had been bent inward.

Paralysis of the muscles and loss of sensation in the region supplied by the peroneal nerve were noticed in one of the patients a few days after the accident, and persisted; when he left the hospital, five months afterwards, the limb was useless, and the fracture had not united.

The other patient died. The autopsy showed that the fracture passed below the upper tibio-fibular articulation, which, however, was opened.

In the discussion that followed Perrin reported a similar case; the patient's leg was caught between the ground and the body of the horse he was riding, and the head of the fibula was torn off. There was also a diastasis of the knee, and paralysis of the muscles supplied by the peroneal nerve. Two months afterwards the paralysis still existed.

The wide separation of the fragments by the retraction of the biceps makes bony union improbable, but it does not appear in Gurlt's cases that any disability ensued. In Duplay's case the disability was the consequence of the paralysis.

The treatment should be immobilization of the limb, and, in case of associated sprain or dislocation of the knee, measures to control or prevent inflammation of the joint. Immobilization with the knee fully flexed would favor close bony union of the fracture by relaxing the biceps, and possibly the position could be borne for a sufficient length of time.

Fractures of the shaft are produced by direct violence. The displacement is slight because of the support given by the tibia, and the diagnosis is made upon the localized pain and the crepitus. In a case reported by Terrier[1] the bone was broken three finger-breadths below its upper end in a fall down a staircase, apparently by direct violence. There was no displacement. Symptoms of inflammation of the peroneal nerve appeared promptly, numbness and anæsthesia of the dorsum of the foot, painful spasms of the peroneal and extensor muscles, paroxysmal attacks of acute burning pain in the insensitive regions occurring spontaneously or on the slightest touch, and paresis of the corresponding muscles. Improvement began after a month, and the fracture consolidated, but when last seen, nearly a year later, the patient still complained of the paroxysmal pain, and the foot was œdematous.

The only treatment needed by the fracture is immobilization of the foot and ankle, preferably in a plaster or silicate bandage extending from the toes to the knee. The dressing may be removed in four or five weeks, but crutches should be used for a fortnight longer.

[1] Bull. de la Société de Chirurgie, 1880, p. 222.

CHAPTER XXVIII.

FRACTURES OF THE BONES OF THE FOOT.

With very few exceptions these fractures are produced by direct violence or by falls upon the feet from a height. According to the table in Chapter I. they constitute about three per cent. of all fractures. Of 172 cases in Agnew's tables 77 were compound or compound comminuted fractures.

A. Fractures of the Astragalus.—These are commonly the result of falls from a height, the bone being crushed between the calcaneum and the tibia, and the lesion being frequently associated with fracture of the calcaneum and with dislocation at the ankle and fracture of the fibula. In 9 of 10 cases collected by Monahan[1] the cause was a fall upon the foot; in 9 there was also dislocation at the ankle or fracture of the fibula, and in 8 the injury was compound.

The direction and extent of the line of fracture vary greatly; the bone may be divided transversely into anterior and posterior halves, or longitudinally, or horizontally, or into several pieces, and the fragments may be widely separated and displaced.

When there is no displacement or external wound the diagnosis may be very difficult, because the symptoms are not distinctive, and indicate only severe injury to the foot, pain, swelling, inability to bear the weight of the body on it, and perhaps crepitus on handling or flexing and extending it. Mr. Bryant[2] thinks fracture without displacement is more common than is generally supposed, and refers to two cases in which he "removed from boys who had acute inflammation of the bone and joint, following injury, the whole of the necrosed upper articular surface with half the thickness of the astragalus, and in both good results followed." In another case he removed the upper half of the astragalus that had been fractured six months previously and displaced so as to present its upper articular facet inward.

When there is no displacement the treatment is directed simply to immobolize the joint and control the inflammation; after the swelling has subsided the plaster bandage should be applied, especial attention being given to the position of the foot which should be at right angles to the leg in the antero-posterior plane and without the slightest inversion or eversion of the sole. This is a capital point in the treatment of all injuries to, or after operations upon, the ankle which may result in ankylosis.

It is an open question whether a displaced fragment in a case of sim

[1] Quoted by Hamilton, loc. cit., p. 562. [2] Surgery, p. 858.

ple fracture should be removed by incision or should be replaced. The reported cases are too few and the circumstances too various to allow a rule of treatment to be formulated. It seems probable that the displaced fragment will die and provoke suppuration, especially if there is much shattering of the bone or rupture of the capsule and ligaments through which the blood supply comes. Those who have confidence in the antiseptic method would probably not hesitate to remove the fragment, perhaps also the remainder of the bone, immediately; those whose confidence has been shaken by reverses would prefer to wait until nature has shown the limits of her power to repair the damage, unless the displacement was extreme, could not be corrected, and threatened to cause ulceration of the skin. Under such circumstances I should think immediate removal was fully justified.

In compound fractures the fragments should be removed, and probably it is best that all the bone should be removed if the attempt is made to save the member. The principles laid down by Langenbeck[1] for the treatment of gunshot injuries of the ankle will serve as a guide. He urges the early application of the plaster bandage and free incisions for the relief of tension and evacuation of the discharges; fever and pain being more certain indications for the latter than swelling and fluctuation without them. In injury of the astragalus the incision should be made between the extensor tendons of the first and second toes; splinters can be easily removed through it and, if necessary, it can be prolonged to the scaphoid and all of the astragalus removed.

After excision ankylosis should be sought for.

In gunshot fracture of both malleoli and the astragalus with extensive splintering he makes total excision, but if either malleolus is only broken and not splintered he leaves it.

The fundamental principle is to secure thorough drainage, and if the removal of one malleolus and the upper articular surface of the astragalus is necessary for this purpose it should be done.

For the removal of the whole of the astragalus he recommends a T-incision on the inner side, the centre of the horizontal branch lying two finger-breadths below the tip of the malleolus. This gives easy access to the inner and inferior surfaces of the bone and facilitates the division of the internal lateral and the interosseous ligaments.

B. Fracture of the Calcaneum.—This bone may be broken by a fall upon the foot from a height, by contraction of the muscles attached to the tendo Achillis, and by forcible inversion of the sole of the foot. The extent and position of the fracture vary with the causes.

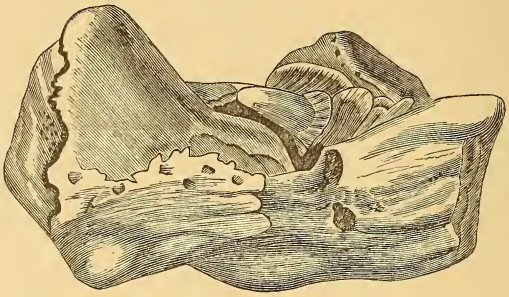
In a fall directly upon the sole the bone is *splintered* or *crushed*, and especially so in its anterior half, and its vertical diameter is diminished by the crushing and its transverse diameter increased (fig. 360). Sometimes the bone is also split longitudinally.

There is some reason to think that forcible pressure upon the ball of the foot, dorsal flexion, resisted by the contraction of the muscles of the calf, may produce the same result by the following mechanism: the arch

[1] Archiv für Klin. Chirurgie, vol. xvi., 1874, p. 479.

of the foot is extended, the thick, strong inferior calcaneo-scaphoid ligament made tense, and the calcaneum broken behind the insertion of this ligament; then, the force continuing to act, the broken bone is further crushed by the astragalus.

Fig. 360.



Fracture of the calcaneum, with crushing.

Gascoyne[1] reported a case in which the bone was thought to have been broken vertically at the junction of its anterior and middle thirds. The patient was a man 44 years old, and the injury was caused by jumping from the wheel of a carriage to the ground, alighting, it is said, on his heel. Swelling and ecchymosis appeared about the ankle and extended rapidly to the knee. There was abnormal mobility of the heel, and crepitus was elicited by moving the heel laterally or by contracting the muscles of the calf. The patient made a good recovery except for exuberant callus below and in front of the malleoli which interfered somewhat with the freedom of the ankle-joint.

The symptoms are somewhat indefinite, and the diagnosis not always easy, as is shown by the fact that surgeons so experienced as Malgaigne, Bonnet, Huguier, and Legouest have mistaken the injury for fracture of the fibula or ankle. The symptoms when the bone has been crushed are increase of its transverse diameter, which, however, may be completely masked by the swelling below and about the malleoli, flatness of the sole and approximation to it of the malleoli, especially of the internal one, pain, and loss of function. Crepitation is either absent or obscure, and the heel is sometimes lengthened, and sometimes shortened, either actually or apparently in consequence of its elevation.

When the direction of the violence with reference to the axis of the leg is such that the foot is adducted or inverted by it the strain is brought upon the external lateral ligament and the sustentaculum tali with the result of producing fracture of the fibula as described on page 579, or rupture of the external lateral ligament, or avulsion of a scale of bone from the side of the calcaneum where the ligament is inserted, or fracture of the sustentaculum tali.

With the first of these we have not here to deal. A case of *avulsion of a scale of bone* came under my observation at the Presbyterian Hospital in November, 1880; the patient had fallen from a height of ten feet,

[1] Med. Chir. Trans., vol. xxxix., 1856.

striking upon his left foot. I saw him on the following day and found the foot and ankle much swollen with obscure crepitation and pain on manipulation of the side of the heel below the outer malleolus. The swelling subsided under lead and opium lotions, and in a few days I could distinctly make out a movable flat fragment evidently detached from the outer side of the calcaneum below the malleolus. The movements of the foot and ankle were normal and painless except when the peroneal muscles were made to contract, then pain was felt below the external malleolus. The sheath of the tendons of these muscles was swollen below and behind the malleolus.

Fracture of the sustentaculum tali was first described by Abel.[1] In his first case the injury was thought to be a Pott's fracture of the ankle, and its real character was disclosed at the autopsy. The patient was a young man who in dismounting from a horse slipped on a stone and turned his foot forcibly inward. He attempted to walk, and the position of the foot then changed instantly to marked valgus. A longitudinal wound three inches long below the external malleolus opened the ankle-joint and the joint between the astragalus and calcaneum. There was tenderness on pressure below the internal malleolus, and on the fibula above the external malleolus. These symptoms together with the apparent broadening of the ankle and eversion of the foot led to the erroneous diagnosis mentioned. Erysipelas set in and the patient died on the fifteenth day.

The fibula and tibia were found uninjured, the sustentaculum tali broken off, and the external lateral ligament divided in the line of the wound.

Abel afterwards saw two cases in which he thought this injury had been received some time before. In both the foot had been violently inverted, and in one the sustentaculum tali seemed to be doubled in size. The symptoms, primary and ultimate, corresponded to the following which he gives as diagnostic of the injury.

1. The mode of production: forcible inversion of the sole of the foot.
2. The immediate change in the position of the foot, from inversion to eversion, and the permanent sinking of the inner border of the foot and internal malleolus (valgus).
3. Shortening of the heel by slight displacement of the calcaneum forward; this can be best recognized by measuring from one malleolus to the other around the heel, and was verified by experiment.
4. Pain and disability.

Fracture by muscular action, contraction of the soleus and gastrocnemii, has been observed a number of times. Malgaigne collected 8 cases, rather briefly reported; in 2 the fracture was caused by a misstep, and in 5 by a fall upon the feet, in two of which it is noted that the patient alighted upon the ball of the foot. The fracture seems to take place always behind the astragalus and sometimes to separate only a portion corresponding to the insertion of the tendo Achillis. The displacement in some cases was slight, in others extreme, $4\frac{1}{2}$ inches from the lower edge of the fragment to the bottom of the heel in Constance's[2]

[1] Archiv. für Klin. Chirurgie, vol. xxii., 1878, p. 396.
[2] Am. Journ. Med. Sc., 1829, p. 222, quoting from an English journal.

case, in which, nevertheless, the patient made a good recovery with perfect use of the limb, although the displacement persisted.

In a recent case reported by Anningson[1] the mechanism of the fracture seems very clear. A woman 42 years old, after stepping down from a doorway to the sidewalk, a distance of about six inches, cried out that she had "put out her ankle." She walked home slowly, a distance of one hundred yards. A fragment of bone was found $2\frac{1}{2}$ inches above the heel in the line of the tendo Achillis which was lacking below it; its lower edge was a little above the level of the lower end of the internal malleolus; it measured one inch transversely and "had been torn off the posterior surface of the os calcis where a cavity could be felt. The whole depth of the bone had not been torn away, but only the upper three-fourths, and the inferior edge of the fragment was tilted backward. The usual treatment of ruptured tendo Achillis was adopted," and eight weeks afterward the patient was able to walk without limping and complained only of some loss of spring.

The *treatment* will vary somewhat with the character and position of the fracture. In the first variety, fracture in the anterior two-thirds with or without crushing, simple immobilization of the limb is all that can be done, except in case of need such additional measures as may seem fitted to prevent or control inflammation.

After fracture of the sustentaculum tali the foot should be immobilized in a plaster bandage or splints with the sole sufficiently inverted to favor reunion of the fragments, but without lengthening of the external lateral ligaments if they have been torn.

After fracture by muscular action with displacement upward of the fragment attached to the tendon the foot should be maintained in the position of complete plantar flexion, and it is sometimes advisable to flex the knee also. This can be done by a plaster dressing, or an anterior splint, or a shoe with a cord extending from its heel to a band about the upper part of the leg or the lower part of the thigh.

C. Fractures of the Metatarsal Bones.—These are usually the result of direct violence, and consequently are often associated with contusion or laceration of the skin even when the fracture is not compound. The first is the one most frequently broken, the fifth is next in order of frequency.

There is but little tendency to displacement except when several bones are broken at the same time, and the usual displacement is of the broken end of either fragment towards the dorsum of the foot.

The diagnosis is made by localized pain, abnormal mobility and crepitus when the first or fifth is broken, and pain when the corresponding toe is pressed bodily backward against the metatarsus.

A simple fracture is not a serious injury, its course is uncomplicated, its result favorable, but a compound fracture may lead to much burrowing of pus, necrosis of the fragments, and grave inflammatory complications, and the treatment should be directed actively to their prevention; if suppuration becomes profuse the freest possible drainage should be

[1] Brit. Med. Journal, 1878, vol. i. p. 128.

provided and counter-openings made on the sole or dorsum as the case may require.

The limb and foot may be supported upon a moulded splint of plaster, felt, or pasteboard, and secured to it with a roller bandage. In compound fracture the gauze dressings will usually immobilize the fragments sufficiently.

D. Fractures of the Phalanges.—These are caused by direct violence and are usually compound, and, as in similar injuries of the hand, may be the starting point of very serious inflammatory complications. Immersion of the foot in a bath containing one or two per cent. of carbolic acid once or twice daily for an hour each time is a valuable means of arresting commencing inflammation.

The dressings of a compound fracture will immobilize the toe sufficiently, and in a simple fracture it is usually sufficient to place the foot on a splint. If it is thought desirable the toe itself may be steadied by strips of adhesive plaster applied longitudinally to its dorsum and sides, or it may be made fast to the adjoining ones.

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